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ECONOMIC BENEFITS AVAILABLE FROM THE PROVISION OF IMPROVED POTABLE WATER SUPPLIES

WASH Technical Report No. 77
December 1992

WATER AND SANITATION for HEALTH PROJECT

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ECONOMIC BENEFITS AVAILABLE FROM THE PROVISION OF IMPROVED POTABLE WATER SUPPLIES

A Review and Assessment of the Existing Evidence

Prepared for the Office of Health
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by

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and
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RELATED WASH REPORTS

Health Benefits from Improvements in Water Supply and Sanitation: Survey and Analysis of the Literature on Selected Diseases. WASH Technical Report No. 66. July 1990. Prepared by Steven A. Esrey, Leslie Roberts, James B. Potach, and Clive Shiff.

A Comparison of the Health Effects of Water Supply and Sanitation in Urban and Rural Guatemala. WASH Field Report No. 352. December 1991. Prepared by O. Massee Bateman and Shelley Smith.

Cost-of-Illness Methodologies for Water-Related Diseases in Developing Countries. WASH Technical Report No. 75. October 1991. Prepared by J.E. Paul and J.A. Mauskopf.

Maximizing the Economic Impact of Urban Water Supply and Sanitation Investment. WASH Technical Report No. 82. December 1992. Prepared by J. Brad Schwartz and Ron W. Johnson.

WASH FINANCIAL MANAGEMENT SERIES

The Water and Sanitation for Health (WASH) Project has developed a series of publications dealing with financial management and cost recovery issues. Currently there are four reports in this series. Titles of these publications are as follows:

Report 1	*Guidelines for Conducting a Financial Management Assessment of Water Authorities* (WASH Technical Report No. 53)
Report 2	*Guidelines for Cost Management in Water and Sanitation Institutions* (WASH Technical Report No. 54)
Report 3	*Principles of Tariff Design for Water and Wastewater Services* (WASH Field Report No. 348)
Report 4	*Guidelines for Financial Planning of Water Utilities* (WASH Field Report No. 370)

The four reports provide an integrated package of financial and management assistance and have been prepared for audiences at varying skill levels within the financial discipline, at both the operational and the administrative levels. The approach of the reports is directive. The reports can be used individually or together. Report 1 is an assessment and diagnostic tool and would logically be the first report used to appraise the current financial management situation of a water supply institution. Weaknesses identified in the initial assessment of such areas as cost management, tariff policy, and financial planning can be addressed by using the other WASH reports in the series.

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EXECUTIVE SUMMARY

While billions of dollars are invested every year in water projects in developing countries, only rarely are these investments subjected to serious economic analysis, mainly because many sector professionals are skeptical that the economic benefits of new water supplies can be determined with sufficient accuracy to be useful. A review of existing literature on the economic benefits of water supply improvements suggests that surprisingly little empirical work has been done on the subject. However, since investment funds are limited, more attention should be focussed on economic analysis as a way to make intelligent choices on level of service and pricing policies.

The four principal research designs used to study the economic benefits of an improved water system are discussed in the report. These include the untreated control group with post-test; the control group with pre-test and post-test; the untreated control group with pre-test and post-test; and designs using case control where individuals exhibiting a specific effect are identified. It is difficult and expensive to carry out any of these designs for a number of reasons, mainly because they take years to plan and implement and are difficult to control. It is not surprising, then, that few studies of economic impact have been carried out.

The term "economic benefits" as used by economists is not synonymous with "economic activity." The introduction of a water supply system might spur economic activity, i.e., new businesses, jobs created, increased agricultural production, and so on. These activities could be measured, but the results would not be what economists call economic benefits. According to economists, an economic benefit is the monetary value that individuals place on a good—in this case, a new water supply. This is measured by people's willingness to pay for such a good.

Many water projects have been evaluated, but only a handful of published studies have attempted to establish a causal relationship between water supply and non-health-related effects in a rigorous, systematic way. Of the four studies reviewed in the report, none attempts to measure economic benefits. In fact, most of the available evidence on the economic benefits of improved water supplies is based on the costs that household will *not* have to incur after the installation of the improved system. Studies have been carried out on three types of cost savings in terms of calories (i.e., food expenditures), time, and money.

Numerous studies of water vending have been carried out in recent years. A review of these studies reveals that water vending is widespread and that water purchased from vendors is extremely expensive. It is not unusual for households to spend 10 percent of their income on vended water. Willingness to pay for water is very high in many areas. It follows that the economic benefits of a water system would be high in locations where water vending is extensive. These are largely peri-urban squatter settlements. Water systems planners should closely scrutinize communities thought to be good candidates for improved water supplies. If water has a high value in those communities, the private sector will likely be active.

In addition to cost savings from new water systems, individuals may also derive consumer surplus on any increased consumption that results from the new system. In order to estimate consumer surplus, economists prefer to use information on individuals' actual behavior and then, based on consumer demand theory, infer what people's maximum willingness to pay for the good must be, given reasonable assumptions about underlying utility functions.

Few studies exist of how households in developing countries respond to higher prices of water, due largely to the absence of available data and the difficulty of obtaining data. Also, it is difficult to find a functional form for the traditional water-demand model because the households' choice is more complex than a continuous single-equation demand model implies. As the price of water changes, the individual household may change both water sources and uses.

The study reviews four papers that attempt an analytical approach to estimate a water demand function for households in developing countries that have met with various degrees of success. These four studies, however, do not provide models that can serve universally as a basis for estimating the economic benefits of improved water supplies.

The hedonic property value model offers an alternative to the water-demand model as a means of estimating the economic benefits of an improved water system. The hedonic property value model is based on the belief that households reveal their preferences for improved water systems in the prices they pay for housing, access to water being part of a bundle of characteristics associated with a particular housing option.

A third approach to estimating economic benefits based on households' actual behavior is a random-utility model that infers willingness to pay for an improved water system from information on the decisions households make as to whether or not to connect to the system.

An alternative approach to the estimation of benefits is to ask respondents a series of structured hypothetical questions about what kind of service they might select and how much they might pay or "bid" for it. This approach is termed the contingent valuation method. In spite of doubts about whether respondents would know how to respond or would tell the truth, there is a growing body of evidence that contingent valuation studies can be successfully conducted in developing countries.

Over the last five years, the World Bank and the U.S. Agency for International Development (A.I.D.) have sponsored ten contingent valuation studies in developing countries to estimate households' willingness to pay for improved water supplies. The results of these studies have been recently summarized by the World Bank Water Demand Research Team, which found that willingness to pay for improved water supplies depends on four factors: (1) socioeconomic and demographic characteristics, (2) characteristics (including costs) of existing sources of water, (3) characteristics of the improved water supply, and (4) households' attitudes toward government policy in the water supply sector.

The studies found that the vast majority of respondents were willing to pay something for improved water supplies. One of the most important determinants of willingness to pay was the existing source. Income was not a major determinant.

Although most respondents were willing to pay, they weren't willing to pay very much. Most bids were low. Two explanations were offered for the low bids. In several cases, households' willingness to pay was heavily conditioned on past governmental policy and a sense of entitlement to water services. Also, there is considerable doubt that government can provide reliable service, something households place a high value on. Another explanation is that payment arrangements are not in tune with the reality of poor people's income flows.

This review makes clear that there is much yet to be learned about the economic benefits of improved water supplies and about household water demand behavior in developing countries. A single research study using the "untreated control group with pretest and post-test" design for estimating the economic benefits of water supply improvements would be an extremely valuable addition to the existing literature.

To summarize, the following tentative observations may be put forward on the basis of the few studies that now exist.

- Economic benefits of improved water supplies can vary widely from one location to another.
- A key determinant of the economic benefit of the improved supply is the characteristics of the existing sources: price, reliability, quality, and convenience.
- Likewise, the characteristics of the improved source have a major effect on the size of the economic benefits. Some new supplies bring negligible benefits, for example, handpumps and public taps, while the economic benefits of private connections can be substantial.
- Households care a great deal about reliability; therefore, reliability is a major determinant of economic benefits.
- Cost savings benefits from improved water sources can be very large.
- When households are collecting water from sources outside the home, time savings appear to be the main perceived benefits.
- When households are purchasing water from vendors, the monetary savings from an improved supply can be equal to as much as 10 percent of household income.
- Water-vending studies suggest that the economic benefits of providing piped water to peri-urban areas are likely to be large.
- The economic benefits of improved water supplies will be great wherever extensive water-vending activities exist; conversely, where there are no water-vending activities, it is likely that households are not willing to pay much for improved supplies.

- Finally, there are economic benefits associated with the increased water use that normally results from the installation of an improved water source, but methods of studying these benefits are still in their infancy.

1

INTRODUCTION

Billions of dollars are invested every year in potable water supply projects in urban and rural areas of developing countries, but only rarely are these investments subjected to serious economic analysis. Most donor agencies and national governments exempt water-supply projects from the kind of economic appraisal routinely applied in other sectors. This is not so because economic questions do not arise. Since investment funds are limited, priorities must be set, and some water-supply projects are selected instead of others. As in the transportation and housing sectors, different levels of service are technologically possible, and choices must be made about whether the higher levels of service are worth the increased costs. Pricing and tariff policy are just as important in the water sector as elsewhere because cost recovery is often an important objective of water utilities and because water is a scarce resource that must be allocated among competing uses. The widespread lack of economic analysis in the planning and appraisal of water projects is thus not due to an absence of important economic issues.

Economic analysis involves the balancing of the costs and benefits of human actions such as investment decisions and regulatory and pricing policies. Economic analysis is not widely used in the water supply sector because many professionals working in the sector are doubtful that the exercise of balancing costs and benefits is useful. There are two principal, distinct reasons for these misgivings, each with different implications for the ways in which economic information can be used in the policy and planning process.

First, many professionals in the sector believe that a clean water source should be provided to everyone as a basic right, or that it is a "merit good" that should not be subject to the usual economic criterion. This notion has been reflected in the past in numerous conference declarations, speeches, and films. The basic argument runs along the lines that water is the "basis of life" and is "beyond price."

Second, there is considerable skepticism among sector professionals that the economic benefits of new water supplies can be determined with sufficient accuracy for the estimates to be useful for practical purposes. One of the principal concerns is whether individuals can truly appreciate their preferences for clean water (and thus the benefits they are likely to derive) *before* an improved water system is installed. In this case, the disagreement is not over whether one would *like* to know the economic benefits of water projects in the abstract, but whether doing so is feasible given time and resource constraints. Put another way, many people doubt whether the quality of the information gained from efforts to estimate the economic benefits of water-supply projects is worth the expense.

Despite these misgivings about the use of economic tools and reasoning in the water sector, some professionals find that economic analysis is useful to convince themselves about the wisdom of investing in a particular water-supply project. Correspondingly, some water-sector professionals feel that economic analysis is useful to convince others about the advantages and disadvantages of a water project. As illustrated in Table 1, these divergent assessments yield four possible situations (or cases).

Table 1

Different Uses for an Economic Analysis of a Potable Water Supply Project

	Economic analysis is ...	
	not useful to convince oneself of the wisdom of a water supply project	useful to convince oneself of the wisdom of a water supply project
Economic analysis is **not** useful to convince others of the wisdom of a water supply project.	Case 1	Case 2
Economic analysis is useful to convince others of the wisdom of a water supply project.	Case 3	Case 4

Professionals in Case 1 find little use for economic analysis in the potable water sector, either for understanding the pros and cons of an investment themselves or for making a case for water-sector investments versus investments in other sectors (or for one water project versus another). There are many such individuals working in the water sector. In addition to the two explanations cited above for not doing economic analysis, such individuals often believe that the health benefits of improved water supplies are so large relative to the costs that a careful cost-benefit analysis will approve all water-supply projects by a wide margin. If this is the case, an economic analysis is unnecessary because the result is known in advance.

In our view, Case 1 is not an intellectually credible position. It is true that human communities cannot exist without daily access to a source of water, but for just this reason it is important to be clear about the relevant investment decision. It is never the case that an economic appraisal of a water-supply investment requires one to know the *total* benefits of *all* water to a community's inhabitants; rather one needs to know the benefits of improving the level of service in terms of the quality and quantity of water *relative to the existing water sources*. Also, there is simply not much known about the relative magnitude of health- and nonhealth-related benefits of water supply improvements.

At the other extreme, individuals in Case 4 believe in the use of economic analysis to convince themselves and others about appropriate courses of action in the water sector. Such individuals might be termed "true believers" and are most likely to be trained economists. In fact, while many economists working for international aid organizations and development planning ministries have argued in favor of the use of economic appraisal methods in the potable water supply sector, very few have actually attempted to measure the economic benefits of water-supply projects. Their enthusiasm is thus often based on principle, not actual experience with applying economic methods and successfully obtaining policy-relevant information.

Individuals in Case 4 are not the only ones with an interest in developing a better understanding of the economic benefits of potable water supply projects and in improving the techniques for estimating such benefits. Individuals in Case 2 find that economic analysis is useful for convincing themselves about the appropriateness of alternative investments in the sector, but not useful for convincing policymakers and other sector colleagues with whom they associate. Given the widespread skepticism about the use of economic appraisal methods among sector professionals, this is a credible intellectual (and political) position.

Alternatively, individuals in Case 3 may feel that economic analysis has relatively little to offer in terms of helping prioritize or select investments. They may feel that an economic criterion should not be the sole basis for assessing projects (or that an economic criterion is not relevant to the decision at all) but still find economic analysis useful to convince others about the wisdom of a project or policy. Individuals in Case 3 may thus subject a project to a personal, multicriteria appraisal, and then, if they judge the project acceptable on such grounds, rely solely on economic arguments to make the case for the project or policy in a public or bureaucratic forum.

This report has been written for individuals in Cases 2, 3, and 4, all of whom have an interest in learning what is known about the economic benefits of improved potable water supplies and how these benefits are measured, albeit for somewhat different reasons. The report reviews the available empirical evidence on the economic benefits of water supply projects. The economic aspects of improvements in health are not, however, specifically addressed because they are included in two other publications of the Water and Sanitation for Health Project (Esrey *et al.*, 1990, and Paul and Mauskopf, 1991).

Chapter 2 presents an overview of the research-design issues involved in an investigation of the consequences of a water supply intervention. Chapter 3 provides an overview of what economists mean by the term "economic benefits" and the units in which they are measured. Chapter 4 reviews several of the better evaluations of water projects to see what can be learned from them. Chapter 5 examines the available evidence on the cost savings that individuals obtain from improved water systems (in terms of calories expended, time saved by no longer having to fetch water from distant sources, and monetary savings from not purchasing water from vendors) .

Chapter 6 reviews three types of empirical studies for estimating economic benefits that are based on individuals' actual behavior: (1) traditional water-demand models, (2) hedonic property value models, and (3) random utility models. Chapter 7 turns to the available evidence on economic benefits obtained from contingent valuation studies (i.e., individuals' responses to hypothetical questions). Finally, Chapter 8 summarizes our major findings and conclusions and offers suggestions for future research. The appendix summarizes selected studies designed to estimate the consequences of other types of infrastructure investments.

Although we have tried to write this report for individuals in Cases 2, 3, and 4, some parts are clearly intended for noneconomists and other parts for economists. This means that some sections will necessarily be tough going for noneconomists. We apologize in advance for this problem of multiple audiences, and suggest that noneconomists may want to skip Chapter 6.

There are two subjects that this report does not address. The first is the issue of the *macroeconomic effects* of infrastructure investments in the potable water supply sector. Most of the literature on the *macroeconomic effects* of infrastructure investments has focused on the United States or other industrialized countries. Also, it usually deals with physical infrastructure in general, not potable water supply per se. Nevertheless, it is important to recognize that the microeconomic literature reviewed here is unable to determine many of the potential synergistic effects of potable water supply projects, nor does it measure well the value of improved water supply in terms of increased production.

Second, little is said about the economic benefits from water *quality* improvements. This is in part because many of the benefits of water quality improvements to households are probably health-related and because there is little literature on the subject of nonhealth-related effects of water quality improvements. Also, the theoretical framework and methods presented for measuring the economic benefits of increases in water quantity are easily extended to water quality improvements.

2

ESTIMATING ECONOMIC BENEFITS: THE RESEARCH PROBLEM

2.1 Elements of Research Design

How can one really *know* whether economic benefits result from the installation of an improved water system? To establish a causal relationship between an improved water system and economic benefits to individuals in a community, it is clearly necessary to know what is meant by "economic benefits" and how these can be measured. We examine these topics in the next chapter. But before beginning our discussion of economic benefits, it is important to have a clear sense of how one can be confident that a causal relationship exists between the installation of an improved water system and *any* kind of hypothesized effect or consequence (e.g., time savings, increased water consumption, improved health, etc.)—not just "economic benefits."

Research projects attempt to make valid inferences about causal relationships by comparing data (pertaining to the variables of interest) from different "situations" so that the difference in the measured variables indicates the effect of the treatment or intervention. Different types of situations can be compared, and one of the principal objectives of research (or experimental) design is to identify what "situations" are appropriate for such a comparison. Two key concepts are often used in research design to define appropriate comparisons for drawing valid inferences: treatment versus control groups and pretest (*ex-ante*) versus post-test (*ex-post*) data observations.

In a laboratory experiment, the researcher attempts to "administer" a "treatment" to one group of subjects and not to a second group, called the "control" group. By careful construction of the experiment, the researcher attempts to ensure that the *only* difference between the treatment and control groups is that one receives the treatment and the other does not. A comparison can then be made between the treatment and control groups, and any observed differences in the variables of interest can be attributed to the treatment. In other words, it can be inferred that the intervention *caused* the difference between the treatment and control groups.

It is not possible, of course, to install an improved water system in a laboratory setting. The "treatment" must be "administered" in actual communities where it is impossible to maintain strict control of research conditions. Whenever a water system is installed in a real-world field setting, many other things are happening at the same time, and there is always the risk that the researcher will conclude that an effect exists when in fact it does not, or that an effect does not exist when in fact it does.

Four principal research designs can be used in field settings to establish causal relationships between water supply interventions and hypothesized effects. All face potential threats to their validity. To illustrate the application of the first three of these research designs to the problem of identifying the effects of improved water supply systems, we define the following notational system:

Let

X = a "treatment" [in our case the installation of an improved water system];

O_1 = observations of the phenomenon of interest, where the subscript indicates the time period (or sequential order) of the recording of the observations. [We also indicate the timing or order of observations by recording earlier observations to the **left** of subsequent observations.]

2.2 Untreated Control Group with Post-Test Only (Cross-Sectional Design)

The first design is an untreated control group with a post-test only. This design can be illustrated schematically as follows:

X O_1 [Treatment Group]

O_1 [Control Group]

Here the researcher evaluates the situation only after the improved water system (X) is installed. The researcher attempts to identify communities or villages without an improved water system that are *like* the treatment village(s) were *before* the installation of the improved water system(s). Any difference between the observations (O_1) in the treatment and control groups is ascribed to the effect of the improved water system.

The primary threat to the validity of this design is the absence of any pretest data. Although researchers attempt to select samples for the control group that are equivalent to the treatment group, this is generally very hard to do in field settings. For example, the environmental or socioeconomic conditions of the treatment and control villages may differ. Within the context of this design, such a problem can be dealt with by randomly selecting the sample of communities for both the treatment and control groups. The randomization process can thus achieve equivalency between treatment and control groups. In practice, however, it is politically difficult (if not impossible) to randomly assign improved water systems to villages. Also, it is expensive to study a sufficient number of villages to implement such a random selection procedure. This approach is thus financially beyond the scope of small research efforts.

2.3 Pretest/Post-Test Design (Time-Series Design)

The second type of design includes both a pretest and a post-test. This design can be represented as follows:

$$O_1 \quad X \quad O_2$$

The pretest observations (O_1) are recorded on a single group of individuals (there is no control group). After these individuals receive an improved water system (X), the researcher returns to measure the post-test observations (O_2). The two sets of observations are compared, and any difference is attributed to the treatment. The individuals studied could be from one or more communities.

The main threat to the validity of this design is that some other change will occur in the village(s) besides the installation of the improved water system. This extraneous factor could either cause the change in the measured effect (and the researcher would wrongly conclude that the change was the consequence of the improved water system) or cancel out the effect of the improved water system (and the researcher would incorrectly conclude that the improved water system had had no effect). A control group is required to reduce the risk of such mistakes.

2.4 Untreated Control Group with Pretest and Post-Test (Time-Series Design)

The third research design, an untreated control group with both pre- and post-tests, combines the strengths of the previous two designs. It may be expressed schematically as follows:

O_1	X	O_2	[Treatment Group]
O_1		O_2	[Control Group]

Here, both treatment and control groups are identified and observations of both are made before and after the treatment is administered. From the baseline data it should be possible to verify that there are no statistical differences between the treatment and control groups before the improved water system is installed. Observations are also made of both experimental groups after the treatment. If the observations (O_1 and O_2) for the control group remain unchanged and the observations for the treatment group change, then one can generally be confident that the difference between O_1 and O_2 for the treatment group is due to the improved water system.

This is the strongest, most reliable of the three research designs. This design is even more powerful if additional observations can be made of the treatment and control groups in later periods (e.g., periods 3 and 4). This design is, however, the most expensive to implement. One potential risk to this design, as well as to the pretest/post-test design, is that the second round of observations (O_2) will be recorded too early, before households (and firms) have had an opportunity to fully adjust to the presence of the new water system.

2.5 Case-Control Design

This fourth research design takes a different approach to the problem of establishing a causal relationship. Rather than starting with the administration of the treatment and then searching for the effect, the case-control method identifies individuals (cases) with the effect and attempts to work backward to determine the socioeconomic or environmental factors that may have led to the effect. This design has proved successful in the epidemiological field in determining the causes of waterborne illnesses such as diarrhea (Briscoe *et al.* 1986).

For example, a researcher using a case-control design in a study of the causes of diarrhea might record data on two groups of individuals that report to a health clinic: those with cases of diarrhea and those with other problems (i.e., controls). Data on the socioeconomic and environmental conditions for each individual would be collected, and the researcher would then use multivariate statistical techniques to calculate the "risk factors" most likely to contribute to the incidence of diarrhea. This approach avoids some of the difficulties introduced in the other designs if experimental groups are not randomly selected.

The unit of analysis for a case-control design might be an entire village or community, rather than an individual household. If the unit of analysis is a community, then a case-control design would use community-level data (or averages) and include some villages with high economic growth rates. The research task would then be to see if villages with dynamic, fast-growing economies were more likely to have improved water systems than villages with poor economies. The villages with high growth may indeed have improved water systems, but it does not follow that the improved water systems contributed to the strong economies. It could be that their economies were strong *before* the installation of the improved water system. Rather than a cause, the water system might be the *result* of high growth: households could afford the water system because they were prosperous.

2.6 Summary

The easiest research design to implement is the "untreated control group with post-test only," but this is also the design with the most serious threats to its validity. It is difficult and expensive, however, to carry out any of the research designs summarized in this chapter. This is true for several reasons. First, water-supply interventions are difficult to control for research purposes. They are expensive and typically impossible to assign randomly to different communities. Second, in many cases water-supply interventions take several years to plan and implement. Also, people need time to adjust to the new water source. The time-series designs in particular thus require careful planning and a long time horizon. Both researchers and funding agencies seldom have the patience and foresight to carry out multiyear research projects. Third, legitimate control groups are difficult to identify, and funding is hard to obtain to study communities and households that do *not* receive an improved water supply.

3

ECONOMIC BENEFITS: THEORY AND CONCEPTS

3.1 What Data Should Be Recorded on Outcomes by the Research Design?

The overview of basic research designs in the previous chapter leaves unanswered the question of *what exactly* the designs should measure? In other words, what data should be recorded in order to measure the "economic benefits" of an improved water system?

If households decide to use an improved water system, many things may change in a community. For instance, the health of individuals in the community may improve because increased water use may lead to a reduction in water-washed diseases and better water quality may reduce the incidence of waterborne diseases. A water-supply intervention may also improve health through less direct ways. For example, if women spend less time collecting water, they may be better able to prepare food for their children and look after their children's health needs. Improved health conditions will result in fewer days of work and school lost to illness and less money spent on medical care. Money not spent on health care may be spent on better nutrition or housing, which may in turn lead to further improvements in health.

There are also nonhealth-related effects of the improved water supply. If women no longer spend as much time collecting water, they may have more time to devote to agricultural or market activities. Time savings may also be allocated to leisure, educational, community, or religious activities. Improved water supplies may permit small commercial enterprises to emerge that would have been unprofitable before. Lower real costs of water may even reduce the price of housing itself, by lowering the cost of mixing cement, and thus change land-use patterns in a community (Fass, forthcoming, 1993).

In effect, the water-supply intervention sets in motion a chain of events, some of which are depicted in Figure 1. Many aspects of the community may change, and it may become a different place in all kinds of ways. How can this change be described in "economic" terms? Analysts may attempt to measure various economic indicators or aspects of *economic activity* in the community before and after the water supply intervention. For example, one could attempt to measure household income, the number of new businesses, jobs created, employment, or agricultural production. Such studies could indeed be very interesting, and the research designs described in the preceding chapter could be used to measure changes in such economic indicators. But such measures of economic activity are not what economists mean by the term "economic benefits."

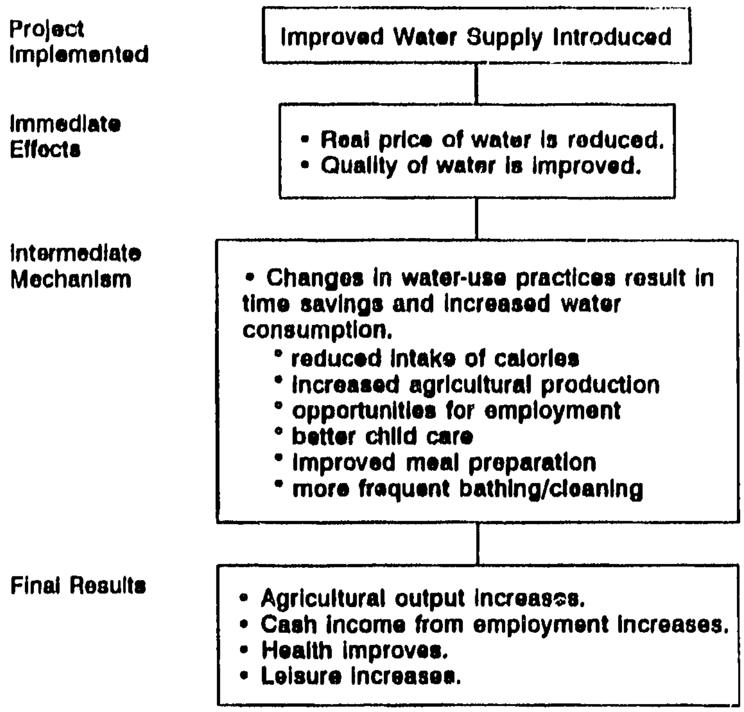


Figure 1

Economic Benefits from Improved Water Supply

In a formal sense, economists define "economic benefits" to an individual in terms of his or her preference satisfaction, or how much he or she *values* all the various effects of the water-supply intervention. The ethical basis for this notion of economic benefits is that public investments, policies, and regulations should be evaluated in terms of their impact on human welfare, or well-being, and that individuals are the best judges of their own welfare.

An important implication of this concept of economic benefits is that to the extent that the health benefits from a water-supply intervention are perceived by an individual, they are a part of the total economic benefits of the project. This means that estimates of health-related and economic benefits from water-supply projects are not mutually exclusive but are to some degree measures of the same underlying effects. In other words, the economic benefits cannot simply be added to the health benefits to obtain an estimate of the total benefits of the project because the two overlap.

There is little evidence, however, on the extent of this overlap. In order to consider the nature of this overlap more carefully, Table 2 depicts four types of different combinations of health- and nonhealth-related, and perceived and unperceived benefits. The cell entries are the percentage of the total benefits from a water-supply project denoted by the respective row and column headings. For example, the entry in Cell 1 is the percentage of total benefits that are health-related and perceived by the users of the water system. Cells 3 and 6 present the row totals showing the split between total benefits that are perceived and not perceived. Cells 7 and 8 show the column percentages of total health- and nonhealth-related benefits. Cells 1, 2, 4 and 5 total 100 percent; as do Cells 7 and 8; and Cells 3 and 6.

Table 2

Distribution of Total Benefits to Users from Improved Water Supplies
(Health/Nonhealth vs. Perceived/Not Perceived)

	Health Benefits	*Nonhealth Benefits*	*Total*
Perceived	Cell 1	Cell 2	Cell 3
Not Perceived	Cell 4	Cell 5	Cell 6
Total	Cell 7	Cell 8	100 percent

A study of the health effects of a water supply project would typically attempt to measure both the perceived and unperceived health benefits (Cell 1 + Cell 4). A study that attempts to measure the economic benefits in terms of individuals *ex-ante* expectations about the effects of the water project would measure all the perceived benefits (Cell 1 + Cell 2). After a project is completed and individuals have experience with the water supply system, some of the benefits that were originally not perceived may become apparent to individuals. If *all* of the health- and nonhealth-related benefits that were not perceived *ex-ante* become apparent after experience with the project, then a study of the economic benefits of the project would measure the total benefits of the project in terms of increased human well-being (Cell 1 + Cell 2 + Cell 4 + Cell 5).

Professionals working in the water-supply sector often have strikingly different implicit notions about the relative magnitudes of health- and nonhealth-related effects and the extent to which each is perceived by individuals. Some of these differences are due to the different disciplinary training of such individuals. For example, many professionals in health education tend to think that the majority of the total benefits are health-related and that the majority of these are not perceived by the users. On the other hand, some economists think that most of the total benefits are nonhealth-related and that most are perceived by the users.

Different experiences in developing countries also shape water-sector professionals' expectations about the relative magnitudes of health- and nonhealth-related effects and the extent to which each is perceived. There is, of course, no reason to think that the cell entries would necessarily be the same in different countries, or even within a particular country. It is entirely possible that in one location the majority of the total benefits would be nonhealth-related and perceived by users and in another location that the majority would be health-related and not perceived by users (or any of the other possibilities). Also, situations in many developing countries are changing rapidly, and what might have been true a decade or two ago may no longer be true today. Sector professionals are often slow to revise their opinions or assessments of the nature of water-supply situations and the benefits possible from improvements.

3.2 Measurement Issues

If "economic benefits" are defined in terms of preference satisfaction, or increased human welfare, the next, obvious question is how economists propose to *measure* such an abstract, ambiguous concept. The notion of human welfare is a multidimensional concept that cannot in fact be measured directly. It is reasonable to believe that an individual's welfare increases if a sufficient supply of improved water is provided, if he or she is better nourished, or has fewer illnesses, but it is unclear what *units* one would use to measure "welfare." Instead of measuring human welfare directly, economists propose to transform it into a unit that can be measured on a single scale.

The unit suggested is money. Economists suggest measuring a person's change in welfare by the maximum amount of money income that an individual would be willing to give up in order to obtain an improvement. (For a change that reduces welfare, the proposal is to measure the amount of money that the individual would require in compensation in order to accept the change.) For example, consider an individual at an initial state of welfare, W_0, that he or she achieves with a money (and noncash) income, Y_0, and a traditional water source, S_0:

$$W_0\ (Y_0,\ S_0) \tag{3.1}$$

Suppose that an improved water system, S_1, is proposed, and that this new water system will increase the individual's welfare to W_1:

$$W_1\ (Y_0,\ S_1) \tag{3.2}$$

The economist would like to know how much this individual's welfare would increase if this new water system were installed., i.e., how large is W_1 minus W_0?

Since there is no reliable, accurate way to measure directly the individual's welfare in these two states directly, economists have proposed a different approach. One can try to determine the maximum amount of money the individual would be willing to pay (WTP) to have the new water system installed. In effect, the individual is asked to consider two combinations of income and water source that both yield the same level of welfare (W_0): one in which personal income is reduced and the new water system is installed and another in which income is not reduced (i.e., stays the same) and the new water system is not installed (i.e., there is continued use of the traditional water source):

$$W_0 (Y_0 - WTP, S_1) = W_0 (Y_0, S_0) \quad (3.3)$$

In other words, the "rational" individual user is assumed to behave in such as way as to (or is asked to) adjust WTP to the point at which these two combinations of income and water source yield the same level of welfare. At this point, WTP is defined as the monetary *value* of the change in welfare, $W_1 - W_0$, resulting from the installation of the improved water source (S_1). This monetary value of the change in welfare is defined as the "economic benefit" to the individual user of the new water system.

It is useful to consider two reasons why an individual would be willing to pay for an improved water system that offered the *same quality of water as the individual's existing source.* If the quality is the same, the real costs of obtaining water from the new source (including any money price) must be less than for the existing source; otherwise the individual would presumably choose not to use the new source. The first reason is that the individual will save money (or time or other costs) obtaining the amount of water he or she originally used from the existing source. This first component of the individual's willingness to pay is termed cost savings and may include not only monetary savings but also savings of time and other resources.

The second reason an individual would be willing to pay for the new source is that, because the water is now cheaper, he or she will generally decide to use more water. Of course, the individual must pay for this increased water use, but perhaps not as much as the maximum amount he or she would be willing to pay. This second component of the individual's willingness to pay is termed the consumer surplus on the additional quantity of water used after the installation of the new water source. The two components of economic benefits are thus the cost savings on the quantity of water used and the consumer surplus on the additional amount of water used as a result of the installation of the new water system.

Figure 2 illustrates these two components of willingness to pay (i.e., economic benefits). Consider a household's hypothetical demand function for water for different uses. Suppose the household is purchasing 20 liters of water per day from a water vendor that delivers water to the door for a price of US$6.00 per cubic meter. In Figure 2 this initial situation is indicated by price, P_1, and quantity, Q_1. The household's total daily expenditure on vended water, $P_1 * Q_1$, is US$0.12 per day and is depicted by the area A + B.

Now suppose that an improved water system is introduced and this household decides to obtain a private connection to the new distribution system. Assume the water utility charges US$0.25 per cubic meter for water from the new system, P_2. There is compelling evidence from around the world that household water use increases substantially when households are provided with a private connection or yard tap in their house: assume here that the household's water use increases to 200 liters per day, Q_2. In this case the household's expenditure on water after the installation of the private connection, $P_2 * Q_2$, decreases from US$0.12 to US$0.05 per day. This expenditure on water after the installation of the private connection is represented in Figure 2 by the area B + D. Note that the relative sizes of A + B and B + D depend on the specific demand function and are not known in advance.

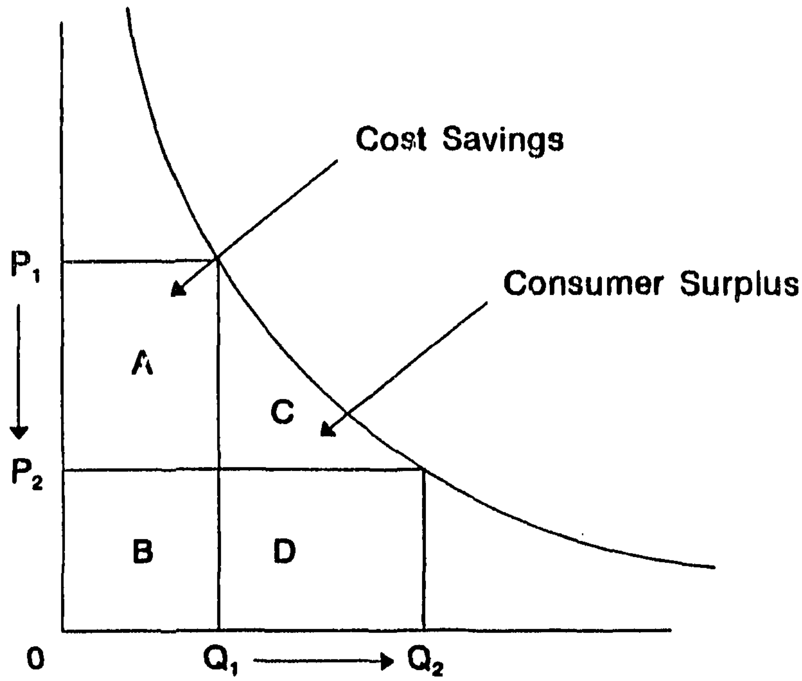


Figure 2

Components of the Economic Benefits to a Household Resulting from the Introduction of an Improved Water System

The correct measure of the economic benefits to the household due to the water-supply improvement consists of these two components: the household's cost savings on the original quantity of water purchased from vendors (area A) and the consumer surplus on the increased water use that results from the installation of the private connection (area C). In Chapter 5 we examine estimates of the cost-savings component of economic benefits. In Chapter 6 we review estimates of economic benefits that include the consumer-surplus component.

It is important to note that the components of the economic benefits of additional water shown in Figure 2 accrue *to the household,* not necessarily to society in general. If this additional water provided to the household must be taken from some other use where it has value (e.g., agriculture, industry), then from a social perspective there is an *opportunity cost* associated with providing this water to the household. In other words, the transfer of water has benefits to the household, but costs to the existing user.

3.3. Summary

Defining "economic benefits" in terms of individuals' willingness to pay for changes in water-supply systems has important implications for the appraisal of water-supply projects. If one were only interested in the effects of a water-supply project on businesses or productive activities, it would be possible to use any of a number of measures of economic activity and then implement one of the research designs described in the previous chapter to see what effect the improved water system had on this measure. However, if by "economic benefits" we mean individuals' willingness to pay for the changes that result from the water-supply intervention, then we must pay particular attention to how individuals behave (or say they will behave) in response to the installation of a new water system.

4

WHAT HAPPENS WHEN IMPROVED WATER SYSTEMS ARE INSTALLED? A REVIEW OF SELECTED EVALUATION STUDIES

The vast majority of so-called evaluations of water-supply projects consists of an individual, or perhaps a team of experts, visiting project sites after the completion of a project, interviewing selected officials (and perhaps a few individuals using the new water system), observing the operation of the new system, and drawing their own subjective conclusions about the effectiveness of the water project. Depending on the experience and skill of the evaluation team, this approach may yield valuable insights or reveal instances of major project failure. It cannot, however, provide verifiable, convincing scientific evidence on the actual effects of the water-supply intervention such as that available from careful implementation of any of the research designs described in Chapter 2.

There are only a few published studies that attempt to establish the causal relationship between a potable water-supply intervention and nonhealth-related effects in a rigorous, systematic way. This chapter reviews four such studies. None of these four studies, however, attempts to formally measure the "economic benefits" of the improved water system as the term is defined in Chapter 3. Rather, the effects of the water supply intervention are measured in terms of such consequences as time savings.

4.1 Drawers of Water: Domestic Water Use in East Africa

The seminal work of White, Bradley, and White (1972) on domestic water use in East Africa is the starting place for many aspects of water-supply policy in developing countries, and this is certainly true as well for our investigation of the economic benefits of improved water systems. White, Bradley, and White's field work in East Africa consisted primarily of a large cross-sectional study of household water use practices in 19 sites without piped water connections and 15 sites with piped water connections. In each site approximately 20-30 households were interviewed about their existing water-use practices, attitudes, and perceptions.

Although their research program was not an evaluation of a particular improved water-supply system, White, et. al. did compare water use by households in sites with improved and unimproved water sources and attempted to identify the factors that determined household water use. Although White, et. al. did not attempt to rigorously estimate the economic benefits (or effects) of improved water systems, two of their findings are of particular relevance here. First, there were substantial differences in the distances households walked to collect water from traditional sources, both among households in a particular village and among households in different villages. The authors examined per-capita daily water use as a function of the distance households walked to fetch water and found that over a relatively wide range of distances (a few meters outside the home up to about 1.5 kilometers) per-capita water use does not decrease much (if at all) as distance increases. Their study had relatively few observations with distances of over 1.5 kilometers, but it appeared that, if distances increased above 1.5 kilometers, per-capita use dropped significantly. For example, the mean per-capita water use for households with collection distances of less than 1.5 kilometers was about 9-10 liters per capita per day. For households with collection distances of more than 1.5 kilometers, it was about 4-5 liters per capita per day. This finding that per-capita water use is relatively insensitive to changes in collection distance up to about 1.5 kilometers was true in both rural and urban areas. These results suggest that, if an improved system of public taps (or public handpumps) were installed in a village in which households currently walk less than 1.5 kilometers to collect water from traditional sources, one would not expect per-capita water use to increase significantly.

Second, White, Bradley, and White's results show that per-capita water use increases dramatically when piped systems are installed and water is brought into the home. This was true even after controlling for such factors as income, education, housing density, and household composition, and it is true in both urban and rural areas. The size of the effect is very large: per-capita water use can increase 10-20 times when a piped water system is installed in a community. The implication of this second finding is also important: if economic benefits depend largely on the amount of water used, then the benefits from the installation of piped water systems are likely to be much greater than from public taps or public handpumps (although the costs are typically considerably higher as well).

4.2 An Evaluation of Village Water Supplies in Lesotho

Feachem *et al.* (1977) conducted an *ex-post* evaluation of water supply projects in villages in Lesotho. The authors selected a nonrandom sample of villages. Some of the villages had received improved water systems funded by the Overseas Development Administration of the British government, and others had no improved system. The study identified five types of potential "benefits": health, time savings, brewing activities, communal gardens, and level of "community development." The authors compared the levels of these five variables in the two groups of villages and attributed any difference to the existence of the improved water system (an "untreated control group with post-test only" design. See Chapter 2.2). The authors concluded that there was no relationship between the existence of an improved water supply and four of the five types of hypothesized benefits: health, brewing, communal gardening, and community development. Women's time allocation patterns were, however, different in the treatment villages (i.e., the villages with the improved water systems) and control villages. Women in the treatment villages spent less time collecting water.

In order to determine how women utilized the time savings from the provision of improved water sources, the research team compiled time budgets for 57 women at various periods of the agricultural year. (The women were not randomly selected.) Women's time was allocated to four main categories: water collection, household work, agricultural work, and social and leisure activity. The authors compared the average time spent in each category in different seasons with the accessibility of water sources. They found that women with more accessible water sources spent more time on leisure and social activities. They concluded that female labor did not appear to be a constraint on agricultural production and that women's time savings from improved water supplies did not translate into increased labor supplies for agriculture or other directly "productive" activities.

The primary contribution of the study was the attempt to compile time-allocation budgets for women with different water sources. The results are limited by the lack of *ex-ante* baseline data and the rudimentary statistical analysis. It could be that women's time-allocation patterns were different in the villages with and without improved water supplies even before the installation of the improved systems. Also, even if the treatment and control villages started out with the same time-allocation patterns, some factor other than the provision of an improved water-supply system may have caused the differences observed in time-allocation patterns. The risk of this threat to the validity of the study design is increased by the nonrandom selection of villages.

4.3 Water Use in Two Villages in Mueda, Mozambique

In August 1982, Cairncross and Cliff (1986) conducted a small study in Mueda, Mozambique, that was similar in several basic respects to the Lesotho study by Feachem *et al.* Cairncross and Cliff again used a simple cross-sectional experimental design to look at water use by households in two villages: one with (Namaua) and one without an improved water supply (Itanda). In Namaua there was a functioning public tap in the center of the village, and the sample households were about 300 meters from the tap. Women spent approximately 10 minutes collecting one bucket of water. The water source for households in Itanda was about four kilometers from the village, and women spent more than two hours walking to and from the source. In addition, queue times at the source were so long that total collection time in Itanda averaged about five hours.

The authors collected information on the amounts of water women in both villages fetched from the respective sources on four days. Data on per-capita water use were obtained for 329 person-days in Namaua and for 338 person-days in Itande. The authors found that households in Namaua collected three times as much water as households in Itanda (11.1 versus 4.1 liters per capita per day). Households in Namaua used most of the additional water collected for increased bathing and clotheswashing.

These findings indicate that as collection time falls, per-capita water use increases, as suggested by consumer demand theory. The decrease in collection time was very large: from five hours per bucket to 10 minutes per bucket. However, water use was still very low (11 liters per capita per day) when collection time was only 10 minutes per bucket. These data suggest that demand for water is quite inelastic with respect to collection time at such low levels of consumption.

Cairncross and Cliff also studied how women's time-allocation patterns differed in the two villages. Their objective was to determine how women would use the time savings resulting from improved water supplies. They compiled time budgets for adult females in the sample households and compared the results in the two villages. They found that women in Namaua used most of their "time savings" for rest and housework, not for agricultural work. On average, women in Namaua spent 106 minutes per day less fetching water than women in Itanda and had 48 minutes more rest per day.

The results from the time-allocation study suggest that in this case the economic benefits of the improved water system do not result from lost opportunities for agricultural labor but are rather the value women assign to time for additional rest and leisure. There is, however, an important caveat to this result: the study was undertaken during a period when demand for agricultural labor was low. It is not known whether women would use the time savings from improved water supply for agricultural labor during the peak agricultural season.

This study has two additional methodological limitations. First, there were only two villages in the sample, and these were not randomly selected. Second, there is no indication that the households studied were randomly selected, nor was any attempt made to control for socioeconomic characteristics of the households with the use of multivariate statistical methods.

4.4 An Evaluation of Water-Supply Projects in Korea

Chetwynd *et al.* (1981) carried out an evaluation of the consequences of installing improved water supply systems in two towns in Korea, Naesu and Dongmyon. The two towns were selected in part because a high percentage of households connected to the new water systems (40-50 percent); in this sense, the projects were preidentified as "successful." The new water systems were installed in 1978, and the evaluation study was conducted in October 1980.

A stratified random sample of households was selected from each of the two towns. In the areas of each town where water was provided, the population was divided into those households that connected to the new system and those that did not. In Naesu, 67 households were interviewed: 34 with a connection to the improved water system and 33 without a connection. In Dongmyon, 66 households were interviewed, but 53 of these had a connection to the new water system.

The authors questioned respondents about their current water-use patterns and then asked them to recall aspects of their water-use behavior before the completion of the new water system. A comparison was then made of households' water-use behavior before and after the installation of the improved water system. The authors found that household water use practices did not change much after the installation of the piped water system. For example, many households continued to do their laundry in a nearby river and boil their water before drinking.

The survey instrument also asked the respondents to make a subjective judgment about the main benefits of the new water system. The users identified three principal benefits: saving time, making life easier, and improving health. Interestingly, the only type of benefit that a significant number of respondents identified as important was "saving time." Most of these respondents had previously been using a community well as their primary water source.

A weakness of this study is that the households that did not connect to the new water system did not constitute an adequate control group. Because all of the sample households were selected from towns in which an improved water system was installed, the households that did not connect to the system cannot be assumed to be the same as those that did. In fact, the authors presented simple cross tabulations to show differences between households that connected to the new water system and those that did not. Another limitation of the study is the use of household recollections of water-use behavior before completion of the new water system. Since no baseline survey was carried out, it is impossible to know how reliable such recollections are. Also, the authors pooled the data from the two towns: no attempt was made to control for differences in the two locations.

4.5 Summary

All four studies use cross-sectional designs to determine how improved water systems affect water use and/or other types of household or community activities. We found no studies in the literature that used a classical *ex-ante/ex-post* design (either with or without control groups) to determine the nonhealth-related effects of a water supply intervention. Although none of the studies attempted formally to measure "economic benefits," White, et. al. do provide some interesting calculations of the cost of obtaining water from traditional sources (which we review in the next chapter).

Nevertheless, the results of these few studies give some intriguing clues about the likely economic benefits of improved water supplies. First, none of the studies indicates that the installation of improved water systems results in dramatic changes in economic activities (as traditionally defined) or production of goods or services. Second, the findings from studies by White, et. al. and Cairncross and Cliff, when taken together, suggest that, when water is collected from outside the home, water use is low in absolute terms and relatively inelastic with respect to collection time. [The collection times found by Cairncross and Cliff in Itande (five hours) are larger than in any of the villages studied by White, et. al. and the average per-capita use levels reported by Cairncross and Cliff are at the low end of the range reported by White, et. al. Their findings are, however, generally consistent with each other.]

Third, time savings from the installation of improved water sources can be substantial in rural areas where people are fetching water from outside the home. The study by Chetwynd *et al.* found that these time savings were important to many people. The studies by Cliff and Cairncross and Feachem *et al.* found that time savings are allocated to rest and housework, not agricultural activities. None of the studies shed much light on how much households *value* these time savings.

5

ESTIMATES OF ECONOMIC BENEFITS BASED ON COST SAVINGS

Most of the available evidence on the economic benefits of improved water supplies is based on estimates of the costs that households will *not* have to incur after the installation of the new system. Households in developing countries currently spend time, energy, and money procuring water from their existing sources. To the extent that these costs are reduced, they will derive economic benefits from a new water system. As noted in Chapter 3, cost savings measure only a portion of the total economic benefits because they do not include the value that households assign to improved water quality and the consumer surplus on any increase in the quantity of water used.

In this chapter we review the evidence from studies pertaining to three types of cost savings: calories (i.e., food expenditures), time, and money (water vending). In addition to these three kinds of cost savings, households in some countries treat their drinking water, either by boiling, filtering, or adding chemicals. Any reduction in time or money spent treating water would also be a benefit of an improved water system, but we have not identified any published studies that attempt to quantify such benefits.

5.1 Calories Expended

In *Drawers of Water: Domestic Water Use in East Africa*, White, Bradley, and White (1972) provided the first detailed calculations of the monetary value of the calories women spend fetching water from sources outside the home. They reasoned that women require increased calories in order to undertake the strenuous work of fetching water from existing sources, and that one of the benefits of an improved water system would be the reduction in food expenditures made possible by not having to carry water. Such estimates of the economic benefits must be low because they assign no value to the time women spend hauling water. They thus represent a lower bound on the total cost savings.

White *et al.* calculated the monetary value of the caloric savings using the following equation:

$$\begin{array}{lclcl} \text{Economic benefits} & = & \text{Calories expended} & \cdot & \text{Food cost} \\ \text{(\$ per day)} & & \text{per day carrying} & & \text{per calorie} \\ & & \text{water} & & \text{(\$ per calorie)} \end{array}$$

The authors collected data on the amount of water collected per day by the households in their sample in each of the study sites. Their estimate of the calories expended per day was calculated as follows:

Calories Expended	=	Calories per kilogram of body weight per hour carrying various loads of water	•	Kilograms per person	•	Number of hours spent collecting water	•	Correction factor for slope of terrain

They measured the time spent collecting water for households in their sample and assumed standard sizes for men (58 kilograms), women (54 kilograms), and children (25 kilograms). Since walking up and down steep slopes requires more energy than walking on flat ground, enumerators made estimates of elevation changes over the terrain to the water source for each household in order to estimate a correction factor. The food costs per calorie expended were based on consumption of a staple food (maize), which was assumed to cost US$0.06 per kilogram in rural areas of East Africa. A kilogram of maize was assumed to generate 3500 calories. To estimate the value of these cost savings per cubic meter of water, White, et. al. simply divided the monetary value of the calories saved by the amount of water each household in the sample collected in a day.

Using this approach, White, et. al. estimated a mean cost savings in their rural study sites of US$0.07 per cubic meter of water fetched from traditional sources. The surprising thing about these lower bound estimates is that they are so large. The average price of water from a private connection to the piped water systems studied by White, et. al. was US$0.15-20 per cubic meter. White, Bradley, and White's estimates of the monetary value of calorie savings thus represent a very substantial proportion of the price charged urban households connected to an improved piped system (approximately 30-50 percent). White, Bradley, and White's estimates thus suggested that the economic benefits of improving rural water supplies are probably larger than was commonly assumed at the time.

5.2 Economic Value of Time Savings

It has been widely recognized that one of the benefits of improved water supply systems is the time savings individuals (usually women) realize by not having to fetch water from traditional sources. However, the notion of "time savings" is often not carefully defined. If a piped water system is installed and a household receives a private connection, then it can be assumed that the collection time is negligible. In this case, the "time savings" is simply the amount of time a ~~household spends collecting water from the old source. However, if the improved source~~ is a handpump or public tap, households must still spend time fetching water. Here the correct definition of "time savings" is the difference in time spent collecting *the original quantity of water*. Because the new system usually results in a reduction in the time required to collect a liter of water, it is expected that households will to some extent increase the amount of water they collect. It is even conceivable that in some cases the total time spent collecting water would increase after the installation of an improved system because the total quantity of water collected would increase so significantly. This does not mean that there are no time savings on the original quantity of water collected (or that there are no economic benefits associated with time savings from the improved water system).

It is often assumed that time savings have "economic value" only if women use them to undertake wage labor or "economically productive work," such as agricultural labor. This is, however, a misunderstanding of the economist's definition of "economic value." The time savings have economic value to the extent that households are willing to pay for them—whatever the reason. In other words, if households are willing to pay to save time, what they do with the time saved is of no concern insofar as the economist is interested in the economic benefits of the improved water system.

There is only one published study that attempts to estimate the economic value of the time households spend collecting water. In a study conducted in Ukunda, Kenya, in 1986, Whittington, Mu, and Roche (1990) examined the water source choice behavior of 69 households. None of these households had a private water connection or yard tap, but all had the option of using three different water sources available in the village. First, they could pay distributing vendors (who haul water in hand-pushed carts) to deliver water to their door for a price of US$0.10 per 20-liter container. Second, they could walk to kiosks and pay US$0.01 to fill a 20-liter container. Third, they could obtain water for free from open wells, where they spent additional time lifting water with a tin tied to a rope. Because the distributing vendors filled their containers at kiosks, there was no appreciable difference in the quality of water available from distributing vendors and kiosks (the quality of water from the open wells was, however, perceived to be lower than that from kiosks and vendors). Households thus faced a rather clear choice between spending money or time.

Data were collected for each household on the time necessary to collect water from the nearest kiosk and open well, the amount of water obtained, and the water source each household actually chose. Since some households chose one source and some chose others, and since the time and money costs of each source were known for each household, the authors were able to derive an upper or lower bound (and sometimes both) on the value each household assigned to the time devoted to collecting water. In effect, the households revealed some information about the value of time spent collecting water by the water-source choice they made. The authors also estimated a multivariate statistical model of households' water-source choices, from which they were able to derive an estimate of the value households assigned to time savings.

The results of the analysis indicated that on average households assigned a value to the time they spent collecting water approximately equal to the market wage rate for unskilled labor (US$0.25 per hour). Households buying water from distributing vendors had an implicit value of time of almost double the market wage rate for unskilled labor. Because Ukunda is a small market town near major tourist activities and thus has significant opportunities for wage employment, one should not attempt to generalize these results to other rural agricultural areas with less wage employment. Nevertheless, the only existing study of the economic value of time spent fetching water found a surprisingly high value. In villages or communities where the value of time spent hauling water is close to the market wage rate, piped water distribution systems are likely to be an economically attractive service level.

5.3 Monetary Estimates of Cost Savings: Evidence from Water-Vending Studies

If a household buys water from a vendor before the installation of an improved water system and then switches to the new system, the money it no longer pays to water vendors represents a (gross) cost savings. This resource savings is conceptually equivalent to calorie or time savings, and should be treated as part of the economic benefits from the improved water system. Over the last few years a series of studies have been carried out on water-vending activities in both urban and rural areas in developing countries (Whittington, Lauria, Okun, and Mu, 1988; Whittington, Okorafor, Okore, and McPhail, 1990; Whittington, Lauria, and Mu, 1991; Lovei and Whittington, 1992; Cairncross and Kinnearb [not dated]; Fass, 1988; Katko, 1991). The findings from these studies provide a number of new insights into the magnitude of the cost savings (and economic benefits) obtained from improved water supplies. The recent research on water vending in developing countries indicates that there are many types of formal and informal water-vending systems in existence and that these activities are much more widespread than has been commonly believed. Table 3 summarizes the extent of water vending activities in selected urban and rural locations in Africa, Latin America, and Asia. Complex water-vending systems are difficult to describe with such summary statistics, but the studies confirm that in numerous urban settings the *majority* of households are purchasing at least some of their water from the water-vending system. In many other locations in both urban and rural areas, a substantial minority of households are purchasing water from vendors. This may mean that they have water delivered by distributing vendors (i.e., those carrying water to the household by cart, hand, or tanker truck) or that they walk to kiosks or to neighbors where they purchase water by the bucket. (Because some of the studies on which the data in Table 3 are based were not conducted throughout the entire urban area listed in the table, the prevalence of water vending may refer only to a particular part of the city.)

The prices households pay for water from vendors are uniformly high, both because transporting water by hand, truck, or cart to an individual's residence is expensive everywhere, and because water-vending arrangements provide many opportunities for monopoly pricing and rent-seeking behavior (Lovei and Whittington, 1992). As shown in Table 4, the price of water charged by distributing vendors is often on the order of US$6.00 per cubic meter. This is extremely expensive. For purposes of comparison, water utilities in developing countries typically charge households with private connections on the order of US$0.10-0.50 per cubic meter (Whittington, Boland, and McPhail, 1991). The prices charged by tanker-truck vendors tend to be lower than prices charged by distributing vendors (although they are still quite high compared to water sold by utilities to households with private connections). However, households must usually buy larger quantities: tanker trucks typically fill 55-gallon drums or larger storage containers.

As a result of high prices and the widespread use of water vendors, many households in developing countries are spending more than US$5 per month for vended water. As shown in Table 4, in the studies reviewed, households in numerous locations were spending US$10-20 per month on water purchased from vendors. Such expenditures on water constitute a much higher percentage of household income than is commonly believed to be feasible. In many places, it is not unusual for many households to spend 10 percent or more of their income on vended water (Table 4).

These studies show that households throughout the world are incurring great financial sacrifices to purchase water from vendors. The studies provide convincing evidence that in many situations households' willingness to pay for water is very high. In situations where water vending is common, the economic benefits of improved water supplies are thus likely to be larger than is typically assumed. It is important, however, to emphasize again that a household's current expenditures to water vendors are not an appropriate measure of the total economic benefits the household is likely to derive from a private water connection; in fact they are an *underestimate* of the economic benefits to the household.

This estimate of a lower bound on the economic benefits to households purchasing from vendors is more valuable than it might first appear because, as noted, in many places, households in developing countries are in fact purchasing from water vendors and because the cost savings are often very large (prices of vended water are high and households often buy substantial quantities of water from vendors). For project-appraisal purposes, if this lower bound estimate of the economic benefits (aggregated over all the affected households) is greater than the cost of the water-supply improvement, the water-resources planner can be confident that the project is economically justified (Whittington and Swarna, 1992).

It is important to note that this lower bound estimate of the economic benefits to a household purchasing from vendors is based on the assumption that there is no difference between water supplied by vendors and water purchased from a water utility. In fact, important differences in quality, reliability, and payment arrangements can make piped water not as close a substitute for vended water as it might first appear (World Bank Water Demand Research Team, forthcoming, 1993; Whittington, Lauria, and Mu, 1991). One of the most important differences concerns the payment arrangements. Purchasing water from vendors typically enables a household to maintain much greater control over its cash-flow situation than is possible with a private connection. Obtaining a private connection usually brings with it the obligation to pay a minimum monthly fee throughout the year, whereas a household is free to stop purchasing from private water vendors whenever it wishes. This flexibility over cash flow provided by water vendors can be a significant economic advantage to a household in a poor economy where there is limited access to credit (Fass, 1988). Also, water vendors may be more reliable than the water service provided by a utility. The implication of such

Table 3

Socioeconomic Environment of Study Areas and
Extent of Water-Vending Activities

Country	*Area/City*	*% of HHS Using Vendors*	*Population of Study Areas*	*Urban vs. Rural*
WATER VENDING ACTIVITIES ARE. . . .				
EXTENSIVE				
Africa				
Nigeria	Onitsha	90%	700,000	U
	Nsukka District	86%	10,000-25,000	R
Sudan	Khartoum	80%	80,000	U
S. America/Caribbean				
Haiti	Port-au-Prince	65%	720,000	U
Honduras	Tegucigalpa	70%	6,000	U
Guatemala	Tierra Nueva	99%	3,000	U
MODERATE				
Africa				
Uganda	Kasangati	25%	2,500	R
Tanzania	Newala	25%	39,000	R
Ghana	Kumasi	32%	600,000	U
	rural areas	na	1,000-2,000	R
Kenya	Ukunda	45%	5,000	R
Asia				
Indonesia	Jakarta (northern)	32%	7,900,000	U
FEW (OR NONE)				
Asia				
Pakistan	Sheikhupura	0%	6,000	R
	Faisalbad	0%	8,000	R
	Rawalpindi	0%	1,100	R
India	with improved water source	0%	6,000	R
	no improved water source	0%	6,000-10,000	R
S. America/Caribbean				
Haiti	Laurent	0%	1,500	R

* Squatter settlement

Table 3 continued

Description of Study Area	*Annual Rainfall (mm/yr.)*	*Index of Water Situation***	*Water Consumption (1/c/d)*	*Average Years of Education*	*% of Adult Illiteracy National Average*	*Annual HH. income in US$ (Yr. Studied)*
market town	2000	4	40	6	65%	1600 (1987)
agricultural	2000	1	7	3	65%	1000 (1989)
squatter area	200	1	24	na	50%	1400 (1987)
capital city	1400	2	11	3	63%	420 (1976)
sqt.*/city edge	850	1	17-22	na	40%	2800 (1986)
sqt.*/city edge	1300	0	33-45	na	45%	1500 (1988)
agricultural	1000	3	3-22	na	43%	na (1984)
agricultural	900	2	8-12	na	41%	110 (1988)
market town	1200	4	na	8	52%	1100 (1989)
agricultural	2000	na	14-30	4	50%	2400 (1987)
small mrk. town	1200	7	20	11	59%	1300 (1986)
capital city	1800	6	22	na	26%	1600 (1988)
agricultural	920	8	24	8	70%	1200 (1988)
agricultural	920	8	32	9	70%	1000 (1988)
agricultural	920	4	33	8	70%	800 (1988)
agricultural	1800	8	34	9	57%	1000 (1988)
agricultural	1800	7	35	7	57%	1400 (1988)
agricultural	1400	3	na	na	63%	800 (1986)

** See Table 5 for an explanation of the water-situation index.

Table 4

Prices of Water Charged by Vendors and Household Payments to Water Vendors

Country Area/city	Type of Vendors	*Price of Water (US$/M³)* Rainy Season	Dry Season	Average	*Average Expenditure for Water* (US$/Mo.)	(% Income)	*Exchange Rate at Time of Study (Year)*
AFRICA							
Nigeria	Tanker Trucks	$0.72	$0.92	—	$8	6%-20%	US$1.00=N4.3 (1987)
Onitsha	by 1000 gal.	—	—	$2.05			
	by drum	$2.05	$2.56	—			
	Retail Vendors	$6.14	$6.65	—			
	Distributing V.	$0.51	$1.02	—			
	Kiosk						
Nsukka	Tanker Trucks	$2.05	—	—	$7	6%-10%	US$1.00=N7.5 (1989)
District	by 1000 gal.	$3.23	—	—			
	by drum	$4.11	—	—			
	Neighbors						
Sudan							
Khartoum	Distributing V.	—	—	$2.03-8.11	$26	17%-55%	US$1.00=LS3.70 (1987)
Tanzania	Distributing V.	—	$6.32	—		na	US$1.00=TS95 (1988)
Newala	Rainwater Sales	—	$4.74	—			

Table 4 continued

Country Area/city	Type of Vendors	Price of Water (US$/M³) Rainy Season	Dry Season	Average	Average Expenditure for Water (US$/Mo.)	(% Income)	Exchange Rate at Time of Study (Year)
Ghana							
Kumasi	Neighbors				$0.7-$1.7	2%	US$1.00=C350 (1989)
Rural areas	Tanker Trucks	—	—	$4.40	$5	2%-3%	US$1.00=C250 (1987)
Kenya							
Ukunda	Distributing V.	$4.70	$9.40	—	$12	9%	US$1.00=KS16 (1986)
	Kiosks	$0.47	$0.47	—			
S.AMERICA/CARIBBEAN							
Haiti							
Port-au Prince	Tanker Trucks	—	—	$3.00-6.00	$6	10%-20%	US$1.00=5 grds (1976)
	Distributing V.	$1.70	$6.60	—			
	Private Kiosk	$1.10	$5.50	—			
Honduras							
Tegucigalpa	Tanker Trucks	—	—	$8.30	$14-$21	8%-12%	US$1.00=LMP2.0 (1986)
Guatemala							
Tierra Nueva	Tanker Trucks	—	—	$2.00	$9	8%	US$1.00=QZ2.5 (1988)
ASIA							
Indonesia Jakarta	Tanker Trucks	—	—	$1.80	$8	6%	US$1.00=PR1700 (1988)
	Distributing V.	—	—	$1.50-5.20			

Table 5

Index of Water Situation in Vending Studies

Country Area/City (Urban = U, Rural = R)		% of HH Using Vendors or Wtr. From Neighb.	Improved Water: Private System Piped, Yard Tap, Hand Pumps (Yes = 1, No = 0)	Reliability (Yes = 1, No = 0)	Quality (Yes = 1, No = 0)
WATER VENDING ACTIVITIES ARE. . . .					
EXTENSIVE					
Nigeria					
Onitsha	:U	90%	1	0	0
Naukka District	:R	86%	0	0	0
Sudan					
Khartoum (squat.)	:U	80%	0	0	0
Haiti					
Port-au-Prince	:U	65%	1	0	0
Honduras					
Tegucigalpa (squat.)	:U	70%	0	0	0
Guatemala					
Tierra Nueva (squat.)	:U	99%	0	0	0
MODERATE					
Uganda					
Kasangati	:R	25%	0	0	0
Tanzania					
Newala	:R	25%	0	0	0
Ghana					
Kumasi	:U	32%	1	1	1
Kenya					
Ukunda	:R	45%	0	0	0
Indonesia					
Jakarta (northern)	:U	32%	1	0	0
FEW (OR NONE)					
Pakistan					
Sheikhupura	:R	0%	1	1	1
Faisalbad	:R	0%	1	1	0
Rawalpindi	:R	0%	1	0	0
India					
with improved water source	:R				
no improved water source	:R	0%	1	0	0
		0%	0	0	0
Haiti					
Laurent	:R	0%	0	0	0

Table 5 continued

Improved Water: Public			*Traditional Water*				
Public Taps, Handpumps, Boreholes (Yes = 1, No = 0)	*Reliability (Yes = 1, No = 0)*	*Quality (Yes = 1, No = 0)*	*Wells, Ponds, Streams, Rivers (Numerous = 1, Few = 0)*	*Reliability (Yes = 1, No = 0)*	*Avg. Time to Trad. Sources (<hr. = 1, >hr. = 0)*	*Qual. of Trad. Water (Satis-factory = 1, Poor = 0)*	*Index of Water Situation (sum of left ten columns)*
1	1	1	0	0	0	0	4
0	0	0	1	0	0	0	1
1	0	0	0	0	0	0	1
1	0	0	0	0	0	0	2
1	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	3
1	0	0	1	0	0	0	2
1	0	0	0	0	0	0	4
1	1	1	1	1	1	1	7
1	1	0	1	1	1	0	6
1	1	1	0	0	1	1	8
1	1	0	1	1	1	1	8
1	0	0	1	0	1	0	4
1	1	1	1	1	1	1	8
1	1	1	1	1	1	1	7
0	0	0	1	0	1	1	3

differences in service characteristics is that the cost savings is only an estimate of a lower bound on the economic benefits; it could differ depending on how households value the differences in service between the water provided by vendors and the water provided by a water utility.

The economic benefits of water supply improvements are likely to be high wherever water vending is extensive. It is thus important to ask *where* water vending activities are most prevalent. The aggregate statistics from the studies summarized in Table 3 are not sufficiently accurate or comparable to permit rigorous multivariate analysis of the different characteristics of communities with more or less vending. Nor were the locations of these studies selected with a random sampling procedure. However, given these caveats, from the data presented in Table 3, it appears that areas where water vending is common are characteristically urban. Places where no one is buying water from vendors tend to be rural. The locations with moderate levels of vending are often smaller cities or market towns.

One might hypothesize that the extent of water vending would increase as income levels in a community increase (this would generally be positively correlated with the extent of urbanization). Figure 3 shows the percent of households using water vendors versus household income in each of the studies. There appears to be little relationship between household income and the extent of vending.

Another factor that might explain the extent of vending is the current water situation that households face. The worse the alternative water sources (in terms of quality, reliability, price, and distance from the household), the more likely a household would decide to choose to purchase its water from a vendor. A crude measure of the availability and cost of other water sources might be the average rainfall in a location. Figure 4 presents data on annual rainfall and the extent of water vending in each of the study areas. There appears to be little relationship between the extent of vending and annual rainfall.

We attempted to develop a better, more systematic description of the adequacy of the existing water sources in the study areas than a simple measure of annual rainfall. An ordinal index was devised based on both objective and subjective judgments of the following factors:

(1) whether a piped water system was available to households in the community, and its reliability and quality;

(2) whether public taps were available to households in the community, and their reliability and quality; and

(3) whether traditional water sources were available to households in the community, and their reliability and quality.

Measures for each of these factors were summed to obtain a cumulative score for each community; these cumulative scores are presented in the last column in Table 5. A high value of the index indicates that the water situation without the vendors is relatively good; a low score indicates that the alternative water sources available to households are poor in several respects.

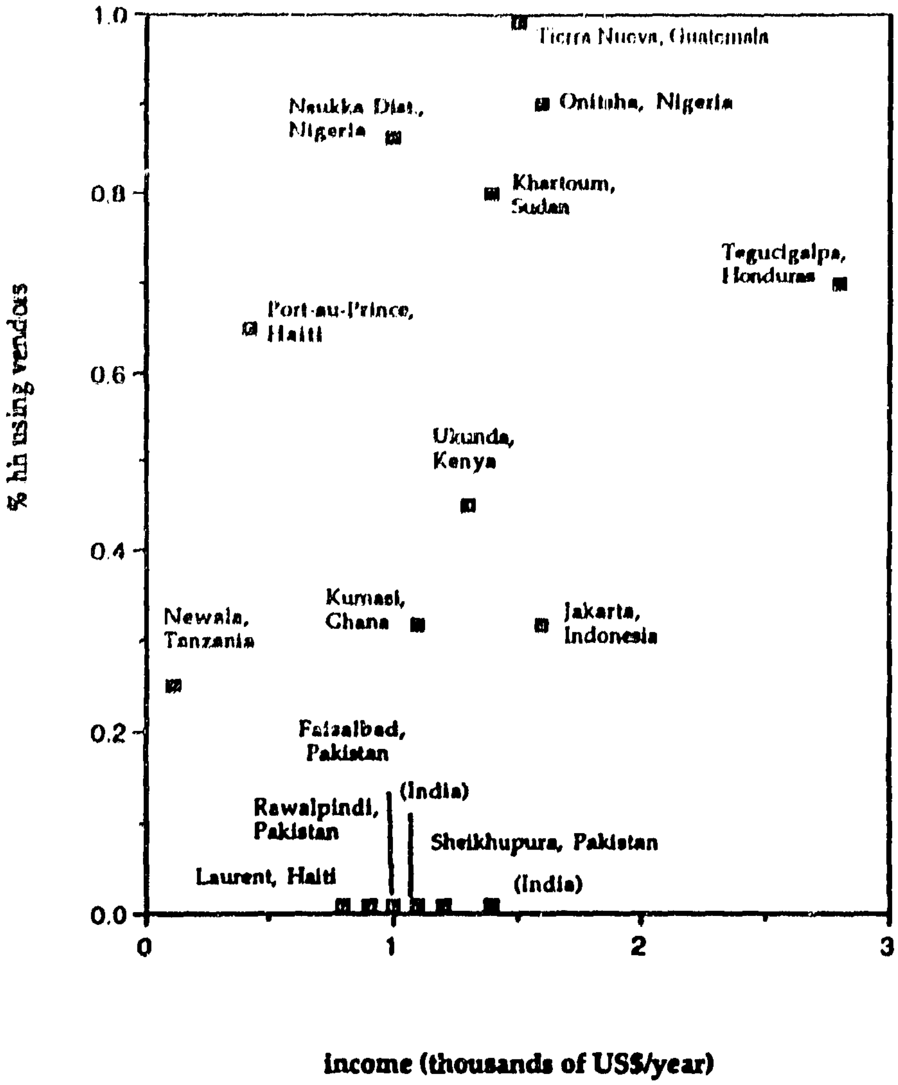


Figure 3

Percent of Households Using Vendors vs. Household Income

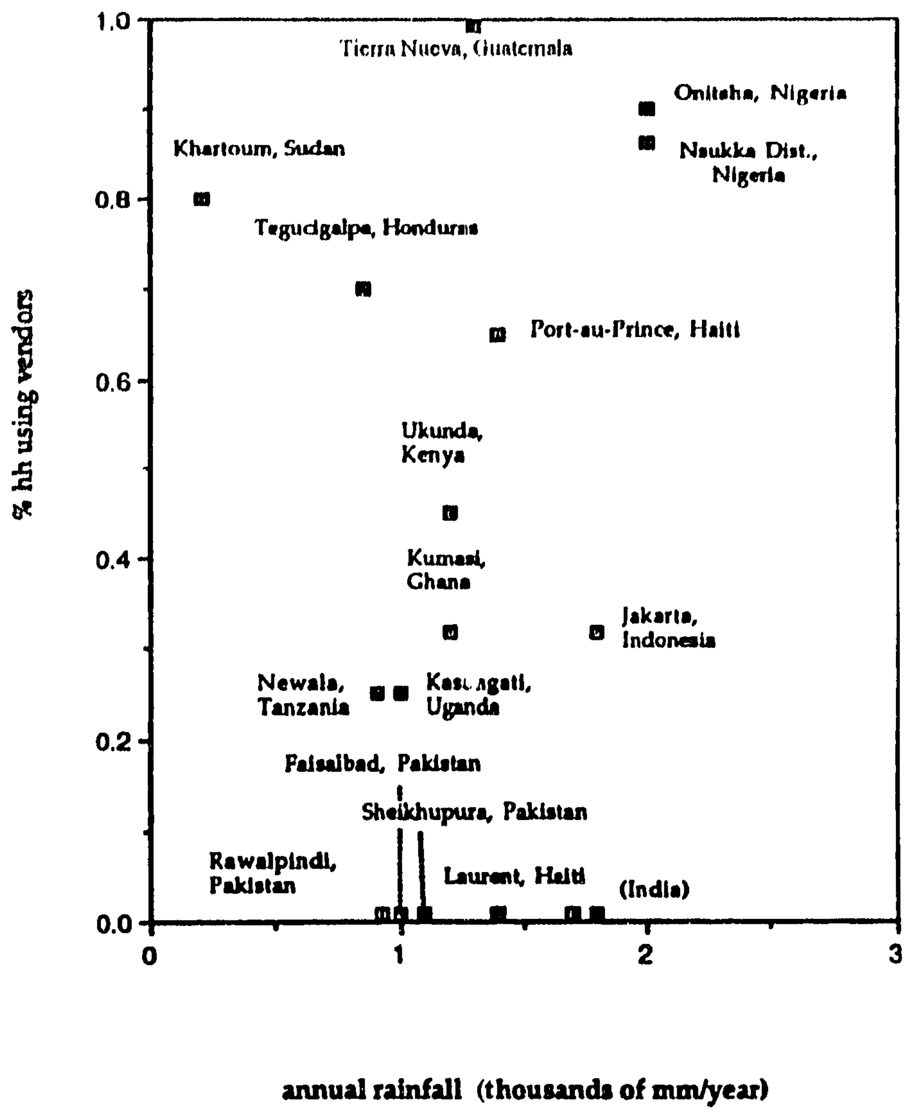


Figure 4

Percent of Households Using Vendors vs. Annual Rainfall

Figure 5 plots the information on the extent of water vending and the score on this water index for each of the communities. In this case there is a clear relationship: water vending is most common in communities where households have few good alternative water sources (i.e., low scores on the water index). Also, by examining some of the "outliers" in Figure 5 (i.e., observations that do not fall on the estimated curve line), the effect of income now appears to come into a little clearer focus. Based on their score on the water index, vending should be more prevalent in places like Newala, Tanzania; Laurent, Haiti; and Rawalpindi, Pakistan. However, these are three of the poorest communities (areas) in the sample, and, even though their scores on the water index are low, their low incomes appear to reduce the extent of vending activities. The higher income locations with poor water index scores all show very high levels of vending (e.g., Tierra Nueva, Guatemala; Tegucigalpa, Honduras).

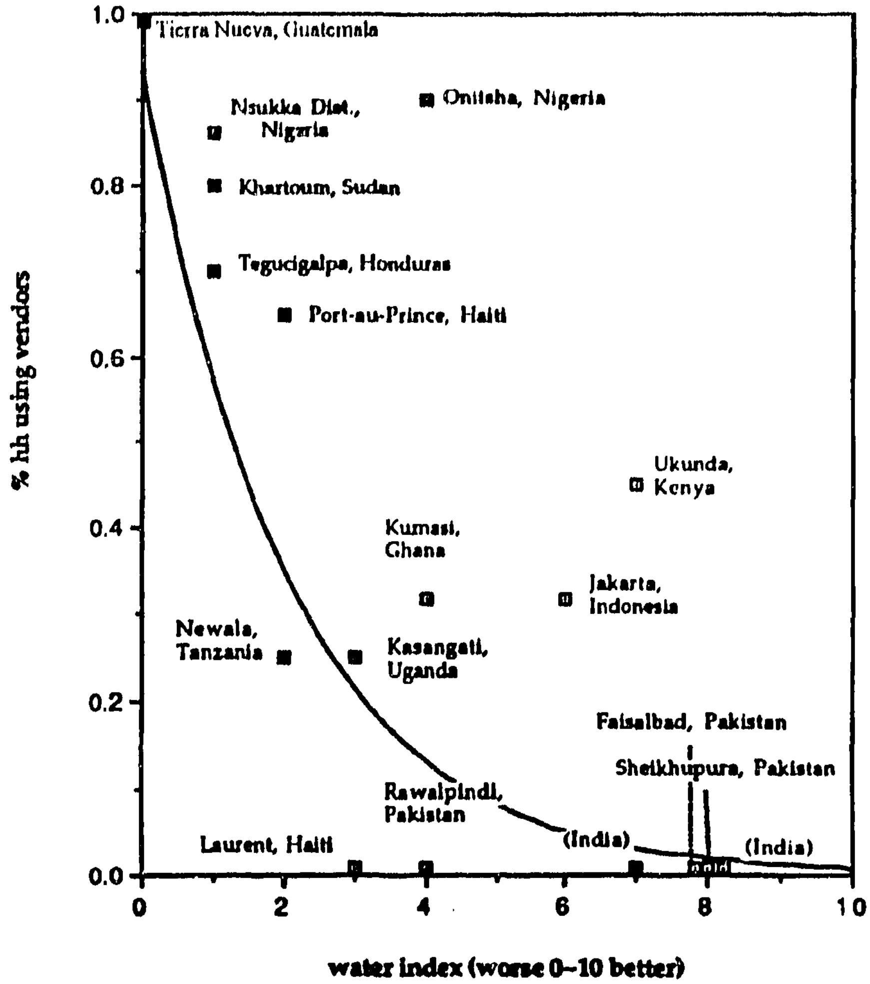
There are three other notable outliers in Figure 5: Ukunda, Kenya; Jakarta, Indonesia; and Onitsha, Nigeria. The study in Jakarta was conducted in the northern part of the city where saltwater intrusion has become a major constraint on the use of water from private shallow wells. Our index probably did not give sufficient weight to the importance of the poor quality of water from sources other than vendors. An improved index would have shifted Jakarta to the right, back toward the estimated relationship.

As previously noted, Ukunda, Kenya, is near the international resorts south of Mombasa, and there are many opportunities for individuals to work for market wages. The opportunity cost of time spent collecting water is thus high, and the available income data probably do not adequately reflect this. The study of water vending in Onitsha, Nigeria, was carried out throughout the city, and it is difficult for the water index to depict the water situation in different neighborhoods. In some places the water situation was much worse than a score of "4" on the water index would suggest.

Obviously these interpretations are very subjective. We believe, however, that future, more rigorous cross-sectional analyses will show that the extent of water vending in a community is largely determined by the characteristics of the alternative water sources available, and, secondarily, by household income.

5.4 Concluding Remarks

The findings from the studies of all three types of cost savings indicate that the magnitude of the resource savings from improved water systems is likely to be large. The findings from our review of water-vending studies suggest that the economic benefits of water-supply improvements are virtually certain to be high in locations where water vending is extensive, and water vending is likely to be extensive in parts of urban areas where alternative supplies are not readily available. Simply put, this means economic benefits are likely to be highest in squatter settlements and other new communities on the periphery of rapidly growing cities in developing countries.



Curve fit: $y=0.93243 * 10^{(-0.2118x)}$; $R^2 = 0.46$

Figure 5

Percent of Households Using Vendors vs. Quality of Other Available Water Sources

The findings from water-vending studies raise another important question for water-resources planners. The absence of water-vending activities in communities thought to be candidates for improved water supplies should give water-resource planners pause. If the benefits of improved water services are great, why hasn't the private sector found this market? In communities where water vending does not exist at present, it will often prove useful to estimate what the price of vended water would have to be for water vending to be a viable commercial enterprise. (This is typically simple to calculate because the majority of the costs for vended water are for transport—either labor for manual water hauling or labor, fuel, and capital for tanker trucks.) If water vendors do not exist in such communities, it is probably because households are not willing to pay this price for vended water.

An estimate of the price of vended water can thus serve as an *upper bound* on the value of water to households. If the costs of providing an improved water supply are *greater* than the value of water supplied (calculated using this upper bound), then the project cannot be economically justified.

6

ESTIMATES OF ECONOMIC BENEFITS BASED ON ACTUAL BEHAVIOR

Cost savings available from the provision of a new water supply system are only one component of the potential economic benefits. Individuals may also derive consumer surplus on any increased consumption that results from the new water system. In order to estimate the consumer surplus associated with the provision of most goods and services, economists have traditionally preferred to use information on individuals' (or households') actual behavior, and then, based on consumer demand theory, infer what people's maximum willingness to pay for the good or service must be given "reasonable" assumptions about underlying utility functions.

Numerous such approaches have been developed for estimating benefits. The most common is to estimate a demand function for the good or service from market data, and then use this information to derive individuals' maximum willingness to pay for different amounts of the good. Other benefit estimation approaches include hedonic property value, travel cost, and random utility models. However, very little careful empirical work has been done in developing countries using any of these techniques for estimating the economic benefits of improved water supplies. This chapter reviews several of the existing studies.

6.1 Traditional Water-Demand Models

6.1.1 An Overview

In the simplest case, a demand function of the following form might be estimated:

$$Q_W = f(P_W, P_O, Y, SE) \tag{6.1}$$

where Q_W = quantity of water demanded by a household per day (liters per capita per day)

P_W = price (or shadow price) of water ($ per liter)

P_O = prices of other related goods and services

Y = household income

SE = other socioeconomic characteristics of the household.

This water-demand function could be estimated with either cross-sectional or time-series data from a sample of households. A cross-sectional study corresponds to the "untreated control group with post-test only" research design described in Chapter 2. In this case, the control group consists of households that have not experienced an increase in their price of water (or face lower real costs of water than other households), and econometric methods are used to compare their water use with that of households that face higher prices. A time-series study compares the same households before and after a price increase and corresponds to the "pretest/post-test" research design. Since in most cases any price increase would apply to all households in a given area, it would not usually be possible to implement an "untreated control group with pretest and post-test" design without selecting a control group outside the study area.

To use this demand function to estimate economic benefits, the inverse demand function is derived:

$$P_W = g\,(Q_W, P_O, Y, SE); \tag{6.2}$$

and the total benefits (including the consumer surplus) of the project B(Qw) are given by:

$$B(Q_W) = \int_0^{Q_W} g\,(Q_W, P_O, Y, SE)\, d(Q_W). \tag{6.3}$$

Surprisingly, there are very few high-quality studies of how households in developing countries respond to higher prices of water. This is largely due to data availability problems. A major problem is lack of data on the quantity of water households consume. When households are not already connected to a piped water system (as is typically the case in many developing countries), primary data collection is required. It is a difficult and expensive undertaking to collect accurate information on the quantity of water households consume for different purposes and it is seldom done.

Economists have thus been forced to work with secondary data available from water utilities in municipalities with private metered connections. Such data sets are rare and often of questionable quality in developing countries. Also, in most urban areas in developing countries, households with metered private connections are likely to be members of the middle- and upper-income classes; the studies may thus reveal little about the water-demand behavior of poorer households. Such water-demand studies are of little relevance in explaining how households would respond to changes in the price of water available from sources outside the home, such as kiosks.

Also, it is extremely difficult to find data sets in which there are substantial differences in the ~~price of water charged different households. This is a particular problem for cross-sectional~~ studies because most households connected to a municipal water system normally face the same tariff structure. It is true that households may pay different average and marginal prices for water due to an increasing or decreasing block tariff structure, but in such cases the price of water is endogenously determined and its inclusion in the model raises a variety of econometric problems. In time-series studies one might expect to be able to observe household water use before and after a tariff increase, but in many cases it is only nominal tariffs that increase. Real prices of water often fall over time due to high rates of inflation and the inability of water utilities to raise prices on a regular basis. In fact, analysts might have more opportunities to model the effects of a *fall* in real water tariffs than an increase. However, in many cities in developing countries water prices are already low (typically well below both the average and marginal costs of supply).

Another limitation of existing water-demand studies in developing countries is that analysts have given little thought to the underlying behavioral implications of different functional forms of the demand relationship. The assumption of a linear functional form implies that the absolute value of the price elasticity of demand is higher (i.e., demand is more *elastic*) at low levels of water consumption. In other words, if the shadow price of water is high and water use is low, a given percentage increase in price results in a greater percentage decrease in the quantity of water demanded than at a lower price level. This situation would be true for some consumer goods and services. However, it seems unlikely to accurately characterize water-use behavior when the shadow price of water (or its real resource cost) is high and household water use is low, as is the case in many developing countries.

For example, when household water use drops to 5-10 liters per capita per day, it is virtually impossible for a household to substitute other goods for water. The household needs a minimum amount of water to survive, and an increase in the price of water simply cannot have much more of an effect on water use (although such price increases can dramatically lower real household income). The assumption of a log-linear specification implies that the price elasticity of demand is constant at all levels of water use. This seems similarly unrealistic when an analyst wishes to model the effects of price changes at low levels of household water use. Thus, at the low levels of water use and high real prices existing in many places in developing countries, the assumption of a linear or log-linear water-demand function is inappropriate.

To develop a better intuitive understanding of this issue, consider a single household that must choose between the quantity of water to use, Q_w, and a composite of all other goods, X. The household is hypothesized to have a utility function, $U(Q_w, X)$, that describes the satisfaction (or utility) that the household derives from various combinations of Q_w and X. The points on each indifference curve in Figure 6 indicate combinations of Q_w and X that yield the household a constant level of utility. The convex shape of the indifference curves indicates that at low levels of water consumption very little substitution is possible between water and other goods. In other words, at low levels of consumption the household must maintain its water-use level in order to stay on the same indifference curve (and thus maintain its existing utility).

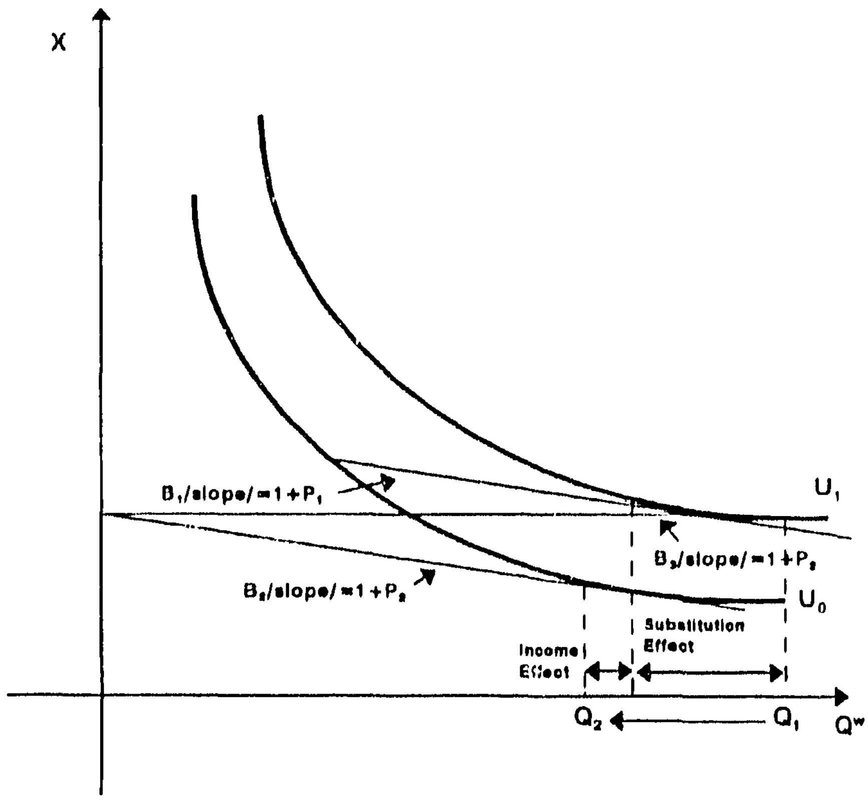


Figure 6

Income/Substitution Effects: When Water Price is Relatively Low

Suppose that initially the household is paying a low price for water, P_1, represented by the absolute value of the slope of the budget line, B_1. At this price, the household uses a large amount of water, Q_1, and purchases X_0 of the composite commodity representing all other goods. At this low relative price of water (P_1) the household is able to achieve a utility level U_1.

Now assume that the relative price of water increases to P_2. This is represented in Figure 6 by the increase in the absolute value of the slope of the budget line, B_2. This higher price causes the quantity of water used to fall to Q_2 and the level of utility that the household can achieve falls to U_0. (Two points on the traditional water demand curve are given by the [Q_1, P_1] and [Q_2, P_2].)

The decrease in the quantity of water used by the household occurs for two reasons. First, the real income of the household has fallen due to the increase in the relative price of water. Even if the household could be compensated for this fall in income by giving it back enough income to maintain its original utility level (U_1) (this compensation is represented by the budget line,

B_1), it would not use as much water as before because the price of water is higher in relative terms and it makes sense for the household to substitute other goods for water. The reduction in water use that would occur if the household were compensated to maintain its utility at U_1 is termed the "substitution effect" and is depicted in Figure 6.

Second, suppose that compensation were paid to the household to maintain its original utility level, and water use was reduced due to the substitution effect. Now imagine that after this adjustment that the compensation was taken away (and the relative price of water remained at P_2). Household water use would fall further because now the household would be poorer. This component of the decrease in water use is termed the "income effect" and is also shown in Figure 6.

In this example, the total decrease in the quantity of water used by the household resulting from the price increase is large because the household has substantial opportunities to substitute water for other goods (this fact is reflected in the slope of the utility function contours over the relevant range of water use—Q_2 to Q_1). The magnitude of the substitution effect is much larger than that of the income effect.

Now consider a second case in which the household has the same underlying utility function, but the initial price of water (P_3) is higher than either of the two prices in Figure 6. The household has sufficient income to still achieve utility level U_1, but total water use is lower (Q_3) because of the higher relative price of water. Now suppose that the price of water increases even more to P_4. In this case, as shown in Figure 7, the total reduction in household water use is less and the size of the substitution effect is much smaller. Unlike in the first case depicted in Figure 6, most of the decrease in water use shown in Figure 7 is due to the income effect, not the substitution effect.

The fundamental underlying problem with the attempt to find a functional form for the traditional water-demand model (that adequately reflects the possibilities for substitution between water of different qualities, and between water and other goods at different price levels) is that the household's choice set is considerably more complex than a continuous single-equation demand model implies. As the price of water changes, the individual household may change *both* water sources and water uses (Whittington and Swarna, 1992). This means that a single-equation water-demand model is likely to be kinked or discontinuous at the point where a household shifts to a new water source and/or a new water use.

Just as one example, suppose a household has a private metered connection, and the price of water is very low. Because water is cheap and land is available, the household decides to irrigate a two-acre garden plot. If the price of water were to rise, the household would use water more sparingly, but as the price rose further, at some point the household might decide not to irrigate at all and just give up the attempt to garden. At this price household water use might fall dramatically. The household's water-demand function would be discontinuous at this price. Other households might not choose to irrigate a large garden at any price of water.

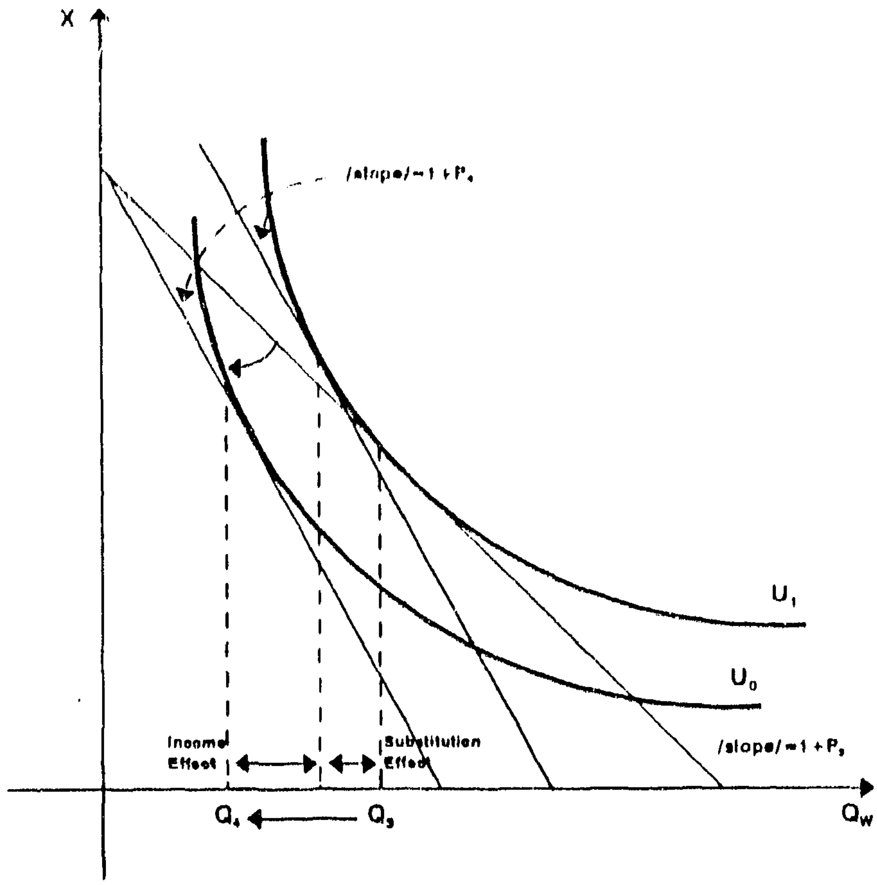


Figure 7

Income/Substitution Effects: When Water Price is Relatively High

Similarly, the available empirical evidence suggests that household water use increases dramatically as soon as a water tap is brought into a house or courtyard. This is in part because the real cost of collecting water is typically reduced when a private water connection is obtained, but it is also because additional water uses (such as washing machines and showers) become technologically feasible.

6.1.2 An Urban Water Demand Model: A Global Cross-Sectional Study

Perhaps the first attempt to estimate a water-demand function for households in developing countries was a study by Meroz (1968) for the World Bank. Working with secondary data from the files of the World Bank, Meroz attempted to explain the variations in average household water use in 38 cities in Africa, Asia, and Latin America as a function of the average "price" of water, average household income, and the weather characteristics of the city. The basic assumption underlying such a cross-sectional analysis is that city-wide averages can characterize a "representative" household, and that the preferences and tastes of households in the 38 cities are identical; the only differences in household water use arise from differences in the price of water, income, and weather.

In general this is the crudest of the available methodological approaches for studying household water demand, and Meroz was acutely aware of its limitations. Not only are these assumptions restrictive, but Meroz did not have data to measure the city wide averages accurately. In fact, he faced major data problems with both the dependent variable (water use) and all of the independent variables. Since data were not available from household water bills, Meroz calculated the average daily per capita water use by dividing total water *production* (minus estimates of industrial water use and water use by households from public taps) by the number of people served by individual connections. Making such an estimate raises numerous problems:

(1) Leakage of water in distribution systems is high in cities in developing countries, so that production can be much higher than actual household water use.

(2) Estimates of the number of people using public taps and their water use are not based on empirical evidence.

(3) In most cities, the number of people served by connections is not known because people without connections often obtain water from households with them.

Calculating water use in this fashion, Meroz found a wide variation in average per capita water use in the cities in his sample (with an average of about 160 liters per capita per day).

Data on household income were not available for cities in the sample, so Meroz used national per capita GDP (gross domestic product) estimates. The independent variable for "price of water" presented even more serious problems. In many cities, water utilities charge households a flat rate per month irrespective of the quantity of water consumed; in such cases, the marginal price of water to the household is zero. In some cities, a portion of the connected households have meters and are charged on a per unit of water basis, and other connected households pay based on a flat rate tariff structure. Information on number of households facing various tariff structures was not available, and Meroz simply used the "average revenue per unit of water sold" as a measure of the price of water in each of the urban areas in his sample.

Meroz tried various functional forms and model specifications; in general the results were quite robust. The following results of a log-linear water demand model with price and income as explanatory variables are illustrative:

$$\log Q_W = \log 1.82 \underset{(4.3)}{- 0.43} \log P_W \underset{(4.1)}{+ 0.41} \log Y \;;\; R^2 = 0.49 \tag{6.4}$$

where the numbers in parentheses are t-statistics. The estimated price elasticity of demand from this model is -0.43; the income elasticity is +0.41. (These estimates mean that a 1 percent increase in the price of water would result in a 0.43 percent decrease in the quantity of water purchased, and that a 1 percent increase in income would result in a 0.41 percent increase in the quantity of water purchased.)

Given the limitations of both the data and the approach, Meroz correctly advises that these estimates should be viewed with considerable skepticism and should be considered only as preliminary evidence that water use does respond to changes in price and income. Despite these caveats, the estimates of price and income elasticities are very close to similar estimates from high-quality studies from industrialized countries (e.g., Howe and Linaweaver, 1967). Meroz did not attempt to use the estimated demand relationships to derive estimates of households' economic benefits from piped water supply (or loss in welfare due to any reductions in water consumption resulting from a price increase), and the results would not have supported such an exercise.

6.1.3 Water Demand on Penang Island, Malaysia

One of the most widely cited papers on household water demand in developing countries is Katzman's (1977) study of households on Penang Island, Malaysia. Katzman analyzed two different data sets. In a cross-sectional study of 1400 households, Katzman examined the effect of income on water use (there was no spatial variation in the price of water, so it was not possible in this part of the study to assess the price elasticity of demand for water). Households in this data set were located in both urban and rural areas; all had metered connections to a piped water system. Urban residents consumed about 20 percent more water than rural households at all income levels. Water use by even the poorest households in the sample averaged 150-175 liters per capita per day. High-income households used about 50 percent more. However, Katzman found that, within a broad range of household income (up to US$3200 per year), income had almost no effect on water consumption. In other words, households with annual incomes of US$500 and US$3000 used essentially the same amount of water.

These results are perhaps not surprising when one considers that the marginal price of water charged households was very low—on the order of US$0.05-0.10 per cubic meter in 1972 (depending on the particular block of the increasing block rate structure into which a household's total water use fell). At such low water prices, the water tariff does not serve to deter water use even for low-income households. Upper-income households probably use more water due to ownership of multiple taps in a house and water-intensive appliances such as washing machines. Based on a simplistic procedure, Katzman estimated income elasticities of 0 when moving from very poor to poor households; 0.24-0.30 from poor to middle income households, and 0.32-39 from middle-income to upper-income households.

In the second part of his study, Katzman studied the effect of a tariff increase on water consumption. In May 1973, the water tariff was increased in Penang Island by 20 percent in the lower block, and 58 percent in the upper blocks. He selected a subset of 164 households in four neighborhoods and obtained some data on their monthly water consumption over the period May 1970-November 1975. Data on household income and other socioeconomic characteristics were not available over the time period, so Katzman divided the sample into four groups in order to control for income (rich urban, poor urban, shophouses, poor rural). In order to control for the different marginal rate increases faced by households purchasing different quantities of water, he divided the *same total sample* into five different groups, each facing the same marginal rate increase.

Linear water demand functions were estimated separately for each of these nine groups of households. Katzman attempted to capture the effect of the price increase by using a dummy variable to indicate whether the monthly household water consumption occurred before or after the price increase. The coefficient on this dummy variable for price was negative, as expected in seven of the nine regressions, but was statistically significant in only two of them. Moreover, the magnitude of these coefficients is generally quite small, indicating that any effect of price on water use—even if it existed—was negligible.

Despite the fact that his parameter estimates for the price dummy were generally not statistically significant, Katzman used them to estimate price elasticities for the nine groups of households. These price elasticities are generally very low—on the order of -0.1 to -0.2 —again indicating that the price had little effect on water use.

Katzman's price elasticity study can at best be summarized as rudimentary, and the reliability of the results should be viewed with considerable skepticism. The effect of the dummy variable for price was statistically insignificant in the majority of the regressions. Household income data were not available. The prices faced by households were very low even after the tariff increase, and there is no indication that the water tariffs in the different periods were adjusted for inflation. The econometric results presented in the paper suggest problems with autocorrelation in the data set that do not appear to have been addressed. Katzman did not use his demand relationships to derive estimates of households' economic benefits from piped water supply.

6.1.4 Water Demand in Nairobi, Kenya

In a 1977 study for the World Bank, Hubbell conducted an analysis of household demand for water in Nairobi, Kenya. Data were obtained from the municipal water utility on household water use from July to September (the dry season) 1974 and from July to September 1975 for 230 households from 11 neighborhoods. As in Katzman's study, all the sample households had private metered water connections. For each household, data were also obtained on its ethnic group, the site value of the property, the site area, and tariffs for water and sewers (not all households were connected to a sewer line). Average household size and income were collected for each of the 11 neighborhoods.

The water and sewer tariffs in Nairobi were increased in 1975. In nominal terms, prices for sewered consumers went up about 23 percent; for nonsewered about 19 percent. However, in real terms, this amounted to approximately 9 and 13 percent, respectively. In 1974, the marginal water charge for nonsewered consumers was about US$0.25 per cubic meter.

Because household-specific income data were not available, Hubbell aggregated the price and quantity information of households in each neighborhood to create a neighborhood average. Twenty-three such neighborhood averages were created, and these served as the data for the estimation of a log-linear demand function. The results of the model estimation were as follows:

$$\log Q_w = \underset{(47.6)}{\log 3.61} - \underset{(8.3)}{0.48 \log P_w} + \underset{(12.7)}{0.36 \log Y}; \; R^2 = 0.66 \qquad (6.5)$$

This model explains variations in average household water use surprisingly well for such a small sample. The estimated price and income elasticities (-.48 and 0.36, respectively) appear reasonable and are similar to results reported from industrialized countries. There are, however, some peculiar aspects of the data set. Average household water use in most neighborhoods is 150-200 liters per capita per day. The only neighborhoods with lower water use (about 50 liters per capita per day) are a few low-income neighborhoods *with sewers*. There are no low-income neighborhoods in the sample without sewers.

Hubbell's results should be viewed as preliminary evidence of the price and income elasticities of demand for water by households with private metered connections in a large urban area. They have little applicability to situations where households are collecting water from sources outside the home. In some respects the sample households in Nairobi were probably more similar to households in industrialized countries than to many poor households in developing countries. Hubbell made no attempt to use the estimated log-linear water-demand function to estimate economic benefits associated with the introduction of a piped water system in another location.

6.1.5 Water Demand in Ukunda, Kenya

Mu, Whittington, and Briscoe (1990) conducted the only published study identified in the literature that attempts to estimate the price and income elasticities of demand for water by households collecting water from sources outside the home. They used the same data set of 69 households in Ukunda, Kenya, described in the previous chapter.

Mu, Whittington, and Briscoe hypothesized that the quantity of water carried home per capita per day would be a function of seven independent variables:

(1) total time the household spends collecting water;

(2) respondent's perception of the taste of water from the chosen source;

(3) total annual household income;

(4) educational level of household members;

(5) number of adult women in the household as a proportion of total household size;

(6) a dummy variable indicating whether the household purchases its water from a vendor; and

(7) a dummy variable indicating whether the household purchases its water from a kiosk.

A price variable is not included in the model directly because each household that chooses a specific type of water source (e.g., well, kiosk, vendor) faces the same money price. However, the shadow price of water to the household is reflected in three of these independent variables. It was expected that households with higher collection times for their chosen water source would use less water per capita because the real resource costs to the household would be higher. Collection time measures the opportunity cost to the household and varies across households in the sample. Also, because vendors charge higher prices than kiosks, and there is no charge for water from wells, the dummy variables for type of source may capture a price effect. However, there are other differences between types of water sources besides price, and these differences cannot be distinguished by these source-specific dummy variables.

Mu, Whittington, and Briscoe estimated this traditional water demand model for four different functional forms using ordinary least squares. The only explanatory variable that was statistically significant in *any* of the four functional forms was the proportion of women in the household. The price and income variables have the expected signs in all four of the functional forms, but are not statistically significant in any of the model estimations. (This may be due to the small sample size.) The estimated "time-price" and income elasticities are very low (-0.16 and 0.07, respectively). Overall, these results are only weakly consistent with an economic interpretation of water-demand behavior.

In summary, these four studies that attempted to estimate traditional water demand function do not provide analytical models that can serve as a basis for estimating the economic benefits of improved water supplies.

6.2 The Hedonic Property Value Approach

The hedonic property value (HPV) model offers an alternative to the traditional water-demand model as a means for estimating the economic benefits to households of an improved water system. The HPV model is based on the belief that households reveal their preferences for improved water systems in the prices that they pay for housing — either in the rent or in the purchase price of their house. Because access to water source can be part of a bundle of characteristics associated with a particular housing option, individuals who value improved water sources will be willing to pay more for a house with a "good" water source than for a house with a "bad" water source. This increased demand should be reflected in the market prices for housing in locations where houses have different water sources.

It is generally relatively easy to explain housing and rental values *if* there is an active, competitive housing market. Two groups of independent variables are typically used to explain variations in housing prices (i.e., to estimate the hedonic price function):

(1) variables that describe the characteristics of the housing unit itself (e.g., number of rooms, size of the lot, etc.) and

(2) variables that describe the characteristics of the neighborhood in which the house is located. (Distance from public facilities, paved roads, quality of schools, environmental quality, distance to the central business district, etc.)

Data on housing characteristics are available from many existing household surveys; data on neighborhood characteristics are often not as readily available.

A variation in the HPV approach is to ask respondents who are living in houses without water services how much they think their house would be worth *if it did have these services.* Although this is a hypothetical question, households are often likely to have a relatively accurate idea of the rental (or purchase price) premium associated with improved water services. However, if this approach is used in squatter settlements, it runs the risk of measuring not simply the benefits of water services, but also the benefits of increased tenure security. This is so because land security is often increased when households pay utility bills.

Households' willingness to pay for improved water services is occasionally estimated in studies of the determinants of housing prices in developing countries (e.g., Follain and Jimenez, 1985). However, only one study has been identified that specifically focused on the use of HPV models for estimating the economic benefits of improved water systems (North and Griffin, forthcoming 1993).

North and Griffin used the HPV model approach to study households' willingness to pay for water in the Bicol region of the Philippines, one of the poorest regions of the country. Data for the analysis come from a 1978 survey of 1903 households. Most sample households used one of the following five classifications of water sources: a private connection in their house (5 percent), water pumped into house or yard from a deep well (30 percent); public tap (24 percent); open well (15 percent); or unimproved surface water source (e.g., lake, river, spring) (15 percent). Private connections in houses and water pumped into houses or yards from a deep well were considered the most desirable water sources.

About 90 percent of the sample households owned their own homes, and only one quarter of the remaining 10 percent reported paying any rent. North and Griffin thus dropped renters from the sample. The head of each household was asked to estimate the value of the dwelling, not including any valuation of the land surrounding the residence. North and Griffin assumed that imputed monthly rent was equal to 1 percent of the estimated property value.

Variables used to explain variations in imputed monthly rent included the type of water source, quality of construction materials of the house, number of bedrooms, size of the housing unit, and location. Two dummy variables were used to describe whether or not a household had piped water in the house or a deep well with water pumped into the house or yard. The third water-source characteristic included in the HPV model was the distance from the house to the water source. Twenty-two percent of the sample households were more than 75 meters from their principal water source. Data on the distance of the house to the nearest town were also included and were expected to be negatively related to rental value.

North and Griffin used two different estimation procedures to derive estimates of households' willingness to pay for improved water sources; both yielded generally consistent results. The hedonic price function (for one of the two procedures) explained almost 60 percent of the variation in rents. Five of seven independent variables were statistically significant and all had the expected sign.

Upper-income households were estimated to be willing to pay about US$2.00 per month for a connection to a piped water system in 1978 prices; middle-income households US$2.25 per month; and low-income households US$1.40 per month. For each income group this was approximately equal to one half their average imputed rent. As a percentage of household income, however, these estimates of household willingness to pay are quite low (e.g., on the order of 1 to 2 percent of monthly household income for the middle-income group). It should be recalled, however, that this estimate is just for access to a private connection; the household would still presumably be willing to pay the required monthly tariff.

North and Griffin found that upper- and middle-income groups were willing to pay about one third less for water from a deep well pumped into their home or yard. On the other hand, households were willing to pay almost nothing to bring public taps closer to their home. These latter results are consistent with those reported by Dworkin (1980) for Thailand, and with the finding of White, Bradley, and White from East Africa (reported in Chapter 4) that household water use does not decrease much as distance from the house to the water source increases (up to approximately 1 to 2 miles). One important implication is that there are common situations in which the economic benefits of providing public taps or handpumps will be negligible.

North and Griffin's analyses show that the hedonic property value approach can provide useful estimates of the aggregate willingness to pay for improved water sources based on actual market behavior. However, the findings from their particular study are limited by the fact that there is no information in the study on the functioning of the housing market in the Bicol region. Also, some communities in their sample probably did not have piped systems at all, and the extent to which households would consider leaving their existing community in search of improved water sources is unclear. Because no information is provided on water tariffs or the terms under which households could have access to private connections, it is difficult to fully understand what the estimates of households' willingness to pay really mean. Finally, the estimates of economic benefits from the HPV model are only of limited assistance for tariff design because they cannot be used to better understand how the quantity of water used by households will change as the price of water changes.

6.3 Random Utility Model Approach

A third approach to benefit estimation based on households' actual behavior is a random utility ~~model. This approach attempts to infer households'~~ willingness to pay for a improved water system from information on the decisions they make as to whether or not to connect to the system.

There is one published study in the literature that attempts to use a random utility model to estimate the economic benefits to households in a developing country of using an improved water system (Altaf, Jamal, Liu, Smith, and Whittington, 1991). The analysis of Altaf *et al.* is based on data obtained from interviews with 378 households in five villages in Punjab, Pakistan. All of the study villages had piped water systems, and some households connected, while others did not. Essentially all households in the study villages already had a private handpump in their house or compound. In addition, a substantial minority of households had also installed electric motors on their own private wells, permitting water to be pumped into an overhead tank for distribution throughout the house to provide indoor plumbing. In these villages, a connection to a public distribution system was a secondary or even tertiary water source and would not be expected to provide the same level of benefits as in places where households were walking significant distances to collect water from outside the home.

In Altaf *et al.*'s discrete choice model, a household's decision to connect to a piped water system is assumed to depend on the utility obtained from the two possible outcomes: connected or not connected. The household's utility is thus assumed to be the maximum value of two conditional indirect functions: utility with connection, V_c, and utility without connection, V_{nc} :

$$V = \text{Max } [V_c, V_{nc}] \tag{6.6}$$

The decision to connect typically requires that a household consider three types of costs: a one-time connection fee (c), a monthly tariff (t), and any private cost of connecting to the distribution line, and installing the associated indoor plumbing (r). This third cost component is related to the distance (d) to the distribution line, and can be specified as r(d).

To illustrate the application of the model, assume that a specific household has an electric motor with operating costs (op) and is assessing the economic benefits of connecting to the public distribution system. The following two equations describe the indirect utility functions for connecting to the public system and not connecting:

$$V_c = a_0 - a_1 (t + op) - a_2 (c + r(d)) + a_3 Y + a_4 SE \tag{6.7}$$

$$V_{nc} = b_0 - b_1 op + b_2 Y + b_3 SE \tag{6.8}$$

where SE here includes socioeconomic characteristics of the household as a proxy for tastes, other household-specific costs of obtaining water, and household attitudes about the quality of the water and whether the government should provide water free of charge.

In the random utility model, the analyst assumes that the decision of each household j, cannot be known with complete certainty. An error term is thus included with each conditional indirect utility function to reflect the unobservable differences in households and their perceptions. The random utility model describes the probability of these decisions as:

$$\text{Prob (connect)} = \text{Prob. } (V_c - V_{nc} > e_{nc} - e_c) \tag{6.9}$$

where e_{nc} and e_c are the errors added to each conditional utility function. Altaf *et al.* assumed that the household's decision to connect to the price system does not affect the marginal utility of income, which implies that $a_3 = b_3$. Then, if Z is defined to be equal to $V_c - V_{nc}$, Z can be expressed in terms of the variables describing the prices and costs of the piped system and the socioeconomic variables (and assuming $a_1 = b_1$):

$$Z = V_c - V_{nc} = (a_0 - b_0) - a_1 t - a_2(c + r(d)) + (a_4 - b_3)SE \quad (6.10)$$

Substituting (6.10) for (6.9), Altaf *et al.* defined the probabilities of the connection decisions observed in their sample for each household. From these expressions it is possible to derive the likelihood function for any sample of households with connect/not connect decisions. For example, the assumption that $e_{nc} - e_c$ follows independent normal distributions with zero expectation and unit variance yields a probit model.

Altaf *et al.* reported the results of numerous specifications for the connection models. Their results indicated that all three components of the costs of connection—tariffs, connection fees, and hookup costs—were statistically significant negative influences on connection decisions.

Altaf *et al.* used the estimated models to derive estimates of households' maximum willingness to pay *annually* for a connection to the piped system, over and above the actual prices (costs) of a connection. This measure of consumer's surplus (CS^*) can be interpreted as the increase in the annual water tariff that would make a household indifferent between connecting and not connecting to the system. CS^* can thus be introduced into (6.7):

$$Vc = a_0 - a_1 (t + op + CS^*) - a_2 (c + r(d)) + a_3 Y + a_4 SE \quad (6.11)$$

and Altaf *et al.* solved for the values of CS^* that equated V_c to V_{nc} for each sample household:

$$CS^* = [(a_0 - b_0) - a_1 t - a_2(c + r(d)) + (a_4 - b_3) SE] / a_1 \quad (6.12)$$

The mean estimates of the annual value households (in the sweetwater areas of Punjab) place on private connections in excess of the tariff and other costs were generally quite low—approximately US$4 for households already connected and US$1.50 for households not connected.

These low estimates of households' consumer surplus available from connections to piped systems should not be attributed to any fundamental limitation of the method. They are consistent with the facts that (1) the alternative water sources available to households in Punjab were in most cases already quite good, (2) the tariff, connection fee, and other costs of connection were substantial, and (3) the reliability of existing public systems was low. In these circumstances one would not expect the consumer surplus from having a piped connection to be large.

The findings of Altaf *et al.* indicate that the random-utility approach can be used to model household water demand and to estimate the economic benefits from piped water systems. Also, prices of water were found to be an important determinant of households' connection decisions. However, with only one existing study, this methodology is still in its preliminary phase of development with respect to estimating the benefits of improved water supplies in developing countries.

7

ESTIMATES OF ECONOMIC BENEFITS BASED ON DIRECT QUESTIONS: EVIDENCE FROM CONTINGENT VALUATION STUDIES

An alternative approach to the estimation of benefits is to ask respondents a series of structured questions about whether they would choose to use a public tap—or choose to obtain a private connection to a piped distribution system—if it were available at a specified price and under certain conditions (such as level of reliability and quality). This approach is termed the "contingent valuation method" (CVM) because the respondent's answers are contingent on the hypothetical conditions or terms of the transaction described in the questionnaire.

This "direct" approach to the estimation of economic benefits has the obvious drawbacks that respondents may not *know* how they would respond to the hypothetical conditions described, or they may know but may not tell the truth. In the water sector, the first threat to the validity and reliability of contingent valuation studies is not likely to be serious because water is very important to many households, and individuals have typically given their water situation and possible improvements considerable thought. However, the contingent valuation method does assume that respondents know *ex ante* the value of improved water services to their household. In the case of the health benefits of improved water supplies, this assumption may not be warranted. Respondents' *ex post* valuations of the benefits of improved water supplies may be greater than their *ex ante* preferences. If so, one would expect that respondents' answers to contingent valuation questions would be underestimates of the economic benefits they would obtain after the improved water services are delivered and households have experience with the new service.

The second threat to the validity of contingent valuation studies—that individuals will not answer truthfully—has preoccupied economists and practitioners of the CVM, but current research in the industrialized countries suggests that it is not as important as economists initially feared. Well-designed and well-executed contingent valuation studies appear to provide as reliable and accurate measures of economic benefits of goods and services *that respondents use* as other available methods.

The evidence on the validity and reliability of the CVM in developing countries is much more sketchy. However, there is a growing body of evidence that contingent valuation studies can be successfully conducted in developing countries. Over the last five years, the World Bank and the U.S. Agency for International Development (USAID) have sponsored a number of contingent valuation studies designed to estimate households' willingness to pay for improved water supplies (Whittington, Mujwahuzi, McMahon, and Choe, 1988; Whittington, Briscoe, Mu, and Barron, 1990; Whittington, Okorafor, Okore, and McPhail, 1990; Whittington, Smith, Okorafor, Okore, Liu, and McPhail, 1992; Whittington, Lauria, Wright, Choe, Hughes, and Swarna, 1992, forthcoming; Altaf, Jamal, and Whittington, 1992; Altaf, Whittington, Jamal, and Smith, forthcoming, 1993; Briscoe *et al.*, 1990; Bohm, Essenburg, and Fox, 1993, forthcoming; Singh, Ramasubban, Bhatia, Briscoe, Griffin, and Kim, 1993, forthcoming). To date, contingent valuation studies of household demand for improved water services have been conducted in Latin America (Brazil, Haiti, Guatemala), Africa (Nigeria, Ghana, Tanzania, Zimbabwe), and Asia (Pakistan, India, and Philippines). The results of these studies have recently been summarized by the World Bank Water Demand Research Team (1993, forthcoming).

The World Bank Water Demand Research Team found that households' willingness to pay for improved water supplies depends on four sets of factors:

(1) The socioeconomic and demographic characteristics of the household, including the education of family members, occupation, family size and composition, and measures of income, expenditures, and assets.

(2) The characteristics of the existing or traditional source of water, including the cost (in terms of money and time required to collect water), the perceived quality, and the reliability of the supply.

(3) The characteristics of the "improved" water supply, including its capital and recurrent costs, the quality of the water provided, and the reliability of the supply.

(4) Households' attitudes toward government policy in the water supply sector and the extent to which they feel entitled to government services.

Without exception, the contingent valuation studies found that the vast majority of respondents interviewed were willing to pay something for improved water services: very few indicated zero willingness to pay. What *type* of service respondents were willing to pay for did vary. Table 6 summarizes the average willingness to pay of households in selected contingent valuation studies for private connections and for access to public taps. In some locations, there was almost no demand for access to public taps, but high demand for private connections (e.g., Brazil). In other places, access to public taps would have provided a great improvement in the existing water situation (e.g., Newala, Tanzania). People were willing to pay more for a private connection, but public taps represented a major step forward and this was reflected in their willingness-to-pay bids (e.g., Haiti).

One of the most important determinants of households' willingness to pay for improved service was found to be their existing water sources (i.e., price, quality, and reliability). This result is consistent with findings in Chapter 5 that water vending is most prevalent in areas with the poorest existing sources. Income was typically neither a major, nor the most important determinant of willingness to pay.

Table 6

Households' Willingness to Pay for Improved Water Systems:
Results from Selected Studies

Country	Area/City	*Average WTP for Private Connection* (US$/mo.)	(% Income)	*Average WTP for Public Tap* (US$/mo.)	(% Income)
AFRICA					
Nigeria	Onitsha	$3.10	2.0%	na	na
	Nsukka District	$1.95	3.0%	$0.94	1.1%
Tanzania	Newala	na	na	$0.34	4.0%
Ghana	Kumasi	$1.56	1.7%	na	na
S. AMERICA/CARIBBEAN					
Haiti	Laurent	$1.42	2.1%	$1.14	1.7%
Brazil	Ceara/Parana	$4.00	2.3%	Nil	Nil
ASIA					
Pakistan	Sheikhupura	$1.11	1.0%	na	na
	Faisalbad	$2.22	2.4%	na	na
	Rawalpindi	$2.78	3.5%	na	na
India	with improved water source	$0.62	0.4%	na	na
	no improved water source	$0.39	0.2%	na	na
Philippines	Santol	$1.26	0.9%	$0.73	0.5%
	Coral Na Munti	$1.17	2.0%	$0.82	1.5%
	Pakigne	$1.07	1.6%	$0.68	1.9%
	Banaga	$0.68	1.0%	$1.07	1.4%

The data in Table 6 indicate a rather low level of mean willingness to pay in many locations for both private connections and public taps, both in absolute terms and as a percent of income. In none of the studies was the mean stated willingness to pay as much as US$5 per month for a private connection. The mean bids for public taps were less than US$1 per month in most of the studies, and generally less than US$2 per month for private connections. In only 3 of the 15 locations where contingent valuation studies were conducted was mean household willingness to pay for an improved level of service 3 percent of income or more.

Although the mean willingness to pay for improved water services is generally low in these studies, there are some important differences between study locations. In the rural agricultural study areas in the Philippines, Pakistan, and India, where alternative water supplies were plentiful, households' willingness to pay for improved services was *very* low—sometimes less than 1 percent of income. In those study locations where willingness to pay for private connections was 3 percent of income or more, the existing water sources were quite poor (e.g. Newala, Tanzania; Nsukka District, Nigeria; and Rawalpindi, Pakistan).

An initial interpretation of these findings might suggest either that the perceived benefits of improved water supplies are low or that respondents did not give accurate answers to the questions. However, the World Bank Water Demand Research Team's analyses suggest that such explanations are often too simplistic. In several cases, households' willingness to pay for improved services was heavily conditioned on past government policy and sense of *entitlement* to water services. Political parties might have promised low-cost or free water, or households might feel that for the sake of equity they should receive subsidized water services because other communities have already obtained them. Also, the studies indicate that households place a high value on reliable water service, and there is a pervasive doubt that governments can provide the high quality, reliable service desired. Thus, one of the reasons that the willingness-to-pay bids from the contingent valuation studies are low may be that households do not believe the improved water service will be reliable.

The World Bank Water Demand Research Team found another explanation for these low bids. Most existing arrangements for collecting payments from households for improved water services obligate households to pay a regular or continual fee. In some areas, households perceive a need for an improved source only during the dry season, because during the rainy season water is readily available and thought to be of good quality. A recurring cash obligation such as a monthly water bill may not be a large proportion of total income, but the fact that it must be paid every month may greatly reduce a household's discretionary income and limit its ability to respond to emergencies.

In summary, the evidence from these contingent valuation studies confirms that households perceive benefits from improved water services and that they are willing to pay something for these benefits. The studies also suggest that the magnitude of these economic benefits is likely to vary substantially from one location to another. This body of research does not support the notion that household demand for improved services has some simple relationship to household income. It does suggest that the benefits that households receive from improved water supplies will depend to a large extent on the reliability of the service and the payment arrangements under which it is offered.

8

SUMMARY AND CONCLUSIONS

The task of estimating the economic benefits from potable water supply improvements has been largely neglected by organizations and researchers working in the water supply sector. Our review of the existing literature on the economic benefits of water supply improvements suggests that surprisingly little serious empirical work has been done on this subject. This is so largely because many professionals have felt that benefit estimates were unnecessary, and because it has generally been believed that the benefits were intangible and extremely difficult to measure. There has not even been any consensus among the few researchers in the field on the definition of "economic benefits."

Our review of the few existing studies suggests that the economic benefits of improved potable water supplies can vary widely from one location to another, and that one of the key determinants of the benefits is the characteristics of the existing sources (i.e., price or collection costs, reliability, and quality). The characteristics of the new water source also have a major effect on the size of the economic benefits. The available evidence suggests that there are numerous situations in which the economic benefits from improved sources outside the home (e.g., handpumps and public taps) are likely to be negligible. In such circumstances the economic benefits from private water connections or yard taps can still be substantial. Existing studies also suggest that households care a great deal about the reliability of their water sources, and thus the reliability of both the existing and improved supplies are major determinants of the benefits derived from an improved source.

The cost savings benefits to households from improved water supplies can be very large. When households are collecting water from sources outside the house, several studies suggest that the time savings from bringing water closer to the home are the main perceived benefits to households, and that these benefits can be highly valued. When households are purchasing water from vendors, the monetary savings from an improved water source can also be surprisingly high. It is not unusual for households in urban and peri-urban areas to spend 10 percent of their income on vended water. Our review of the existing water-vending studies suggests that the economic benefits of providing piped water to peri-urban areas of rapidly growing cities in developing countries are likely to be very large.

In Chapter 5 we also suggest that the absence of water-vending activities in rural (or urban) areas provides important information on the economic benefits of improved water supplies. If water vending is not occurring (and households are not undertaking significant investments to improve private water sources), this is an indication that households are not willing to pay what water vendors would have to charge for water. Economic benefits cannot be greater than this. In general, the economic benefits of improved water supplies will be great wherever extensive water-vending activities exist.

There are also economic benefits associated with the increased water use that typically results from the installation of an improved water source. As discussed in Chapters 6 and 7, there are only a few studies that have attempted to estimate these benefits. The economist's traditional approach of estimating demand curves (and then inferring the economic benefits) has found little application in the water sector in developing countries because of the inability of this approach to adequately model households' source choice decisions and because the data available from water utilities is often of questionable quality. The hedonic property value model and the random utility model approaches have just recently been applied to the problem of estimating the economic benefits of improved water supplies, and although the preliminary results are encouraging, these approaches require further development. More work has been done on the application of the contingent valuation method, and this approach shows considerable promise. However, the terms under which the new water supplies are to be made available need to be carefully specified.

Both the hedonic property value model and the contingent valuation methods require the use of detailed household surveys. A single survey can collect the information necessary for the implementation of both approaches, and the marginal cost of collecting the information for one approach when the other is already being undertaken is low. Combining the contingent valuation and hedonic property value studies in a single investigation thus appears to be a promising avenue for future work on benefit estimation, and would allow the researcher to develop two estimates of economic benefits.

Finally, this report makes clear that there is much yet to be learned about the economic benefits of improved water supplies and about household water demand behavior in developing countries. Almost all of the existing studies use cross-sectional experimental designs. There is not a single research study in the literature that uses the more powerful "untreated control group with pretest and post-test" design for estimating the economic benefits of water supply improvements. Such a research study (or series of studies) would be an extremely valuable addition to the existing literature.

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Appendix

REVIEW OF SELECTED IMPACT EVALUATION STUDIES ON THE ECONOMIC CONSEQUENCES OF INFRASTRUCTURE INVESTMENTS

This appendix reviews four studies designed to estimate the consequences of different kinds of investments in infrastructure. An examination of the problems encountered in the design and execution of these studies reveals lessons for evaluation studies in the water-supply sector.

1. A Study of the Relationship between Investment in Irrigation Infrastructure and Agricultural Productivity

In a study conducted in Orissa State in India, Easter (1977) investigated the effect of improved irrigation systems on agriculture productivity. In the study area, some irrigation systems had been improved by constructing field channels that provided paddy-rice farmers greater control over the timing and quantity of water delivered from a main reservoir. The objective of the research was to determine how these improvements in the irrigation system changed cropping patterns, crop yields, and the use of factor inputs. Easter hypothesized that irrigation improvements would increase overall agricultural production of farmers in a village and that variations in the use of different high-yielding crop varieties would explain much of the variation in the productivity of individual farms.

A cross-sectional research design was utilized. Households in four villages were surveyed during the 1970-71 rainy season and during the 1971 dry season. Two of the villages had improved field channels, and two did not. A random sample of 126 farmers was selected from a list of all farmers in the four villages. The sample was stratified by three farm sizes: small, medium, and large. Approximately 20 percent of the owner-cultivators were interviewed from each of the four villages.

Unlike the authors of the water-evaluation studies reviewed in Chapter 4, Easter used multivariate statistical techniques to isolate the effect of the infrastructure investment. Cobb-Douglas production functions were estimated for each crop season in order to determine how much of the increased crop yield could be attributed to the improved field channels and how much to other factor inputs such as fertilizer, pesticides, and land quality. The following Cobb-Douglas function model and variables were used in the regression analysis:

$$Y_i = K \cdot F_i^{\alpha i} \cdot P_i^{\beta i} \cdot L_i^{\rho i} \cdot D_v^{\theta v}$$
$$\cdot D_m^{\theta m} \cdot D_h^{\theta h} \cdot D_y^{\theta y} \cdot D_d^{\theta d} \cdot D_b^{\theta b}$$

where;

i = type of villages (control or treatment villages)

j = type of land (slopes, dales, or lowland)

Y = per acre rice yields in quintals by land type and farm

K = constant term

F = per acre expenditure on fertilizer and farmyard manure by land type and farm

P = per acre expenditures on plant protection

L = per acre man-days of labor used

D_v = dummy indicating improved villages

D_m = dummy indicating medium level of insect damage (10 to 25% crop loss)

D_h = dummy indicating high level of insect damage (over 25% crop loss)

D_y = dummy indicating farms that used high yielding varieties

D_d = dummy for dales land type (Berna land)

D_b = dummy for lowlands land type (Bahal land)

and α_{ij}, β_i, P_i and θ are parameters to be estimated.

The model was estimated for dry and rainy seasons, separately. Note that a village-level dummy variable, D_v, was used to indicate whether or not the field channels had in fact been improved.

Perhaps not surprisingly, the results of the statistical analysis showed that improvements in the irrigation system increased agricultural productivity in the dry season, but not in the rainy season. Approximately half of the differences in agricultural productivity between farmers in the dry season could be attributed directly to the improved irrigation system.

The findings of the study cannot be easily generalized since they are based on only four villages. Also, it is possible that the use of high-yielding crops and fertilizers may have increased because of the improvement of the field channel. Still, the use of multivariate analysis to control for influences other than the improved irrigation system adds considerably to the confidence one places on the results. Also, because the data were collected in both the rainy and dry seasons, the author was able to examine how the results differed as a function of season. Despite the unavoidable limitations of a small cross-sectional research design, much was learned from this carefully conducted study.

2. The Relationship between Investment in Transportation Infrastructure and Economic Development

In 1977 the Southeast Asian Agency for Regional Transport and Communication Development initiated a research project to estimate the effects of investments in transportation systems in four remote rural areas of Malaysia, Indonesia, Philippines, and Thailand (SEATAC, 1979). The research team hypothesized that investments in transportation infrastructure would reduce the costs of a wide variety of economic activities, and that these reductions would in turn induce changes in many household activities. The team expected to find increased income levels and different income distribution patterns in areas where transportation systems had been improved. Most of the transportation system improvements increased the use of motorized transport and reduced nonmotorized transport (such as ox-carts, canoes, etc.).

A cross-sectional, *ex-post* research design was again adopted. Four study areas were selected, one from each country. In each study area, three administrative units were selected so that the population centers in the administrative units were different distances from the transport improvement. Within each administrative unit, three villages were randomly selected. Approximately 200 household interviews were conducted in the nine sample villages in each study area. In addition to the household interviews, village-level surveys were conducted in each of the sample villages in order to determine the existing transport services, agricultural processing industries, and commercial activities.

The research team relied on respondents' recall of their circumstances and behavior prior to improvement of transportation infrastructure in order to compare the differences in their economic conditions and their transportation behavior before and after the investment. In most cases, it was assumed that respondents could accurately recall their economic conditions and transportation behavior five to ten years prior to the interview.

In order to evaluate the impact of transportation infrastructure investment, the research team focused on four types of impact categories. First, the team examined how much traffic had increased on the improved road (or bridges) since the investment project.

Second, the study examined changes in socioeconomic indicators, such as:

(1) area cultivated or cropping patterns,

(2) ownership of household assets,

(3) frequency of household travel,

(4) use of social services (such as health care and bank credit), and

(5) participation in social organizations.

These data were largely obtained from the household survey. In the case of the agricultural variables in (1) above, the research team acknowledged that the findings of the study were inconclusive because extraneous factors other than the transportation improvements (such as irrigation or high-yielding seed varieties) probably influenced some of the outcome variables. In the Philippines, there were no changes in the area cultivated or the cropping pattern after the transportation infrastructure improvements.

Third, the effect of the transportation improvements on income distribution was examined. Fourth, households were asked about the effect of transportation improvements on their overall quality of life. In the Philippines, most respondents perceived that the improvements had made transport more convenient, faster, and more reliable.

Although the research team collected a large amount of household survey data, no multivariate analyses of the data sets are reported. Conclusions are usually drawn from simple percentage increases in selected variables before and after the improvement. However, there are *two points* that can be learned from this research effort. First, the design attempted to show the regional impacts by choosing villages with different distances from the transportation improvement. Second, the research team tried to evaluate the impact of transportation improvement both through the changes in traffic volume directly, and through the changes in economic behaviors indirectly.

3. The Effects of Investments in Rural Electrification on Agricultural Changes in India

Barnes and Binswagner (1984) investigated the impact of rural electrification investments on changes in agricultural practices in India over the period 1966-1980. They conceived of the effects as a two-step process: electrification would change farming practice and the adoption of new farming practices would induce higher agricultural yields. It was expected that the public investment in electrification would lead to the adoption of electric pumps, tubewell irrigation, and multiple cropping.

Villages with and without electricity were compared for two time periods. Survey data were available from 108 villages located in three states in India. The unit of analysis was the village, not the household. Data were collected on each village in 1966 and then again in 1980. Village-level information was collected from structured interviews with four or more village leaders, from village records, and from the state electricity boards.

Secondary data were also available for each village on crop yields, area irrigated, area double-cropped, and demographic and socioeconomic characteristics of the population.

Multivariate statistical methods were used to isolate the effect of the electrification investment on agricultural productivity. The major question to be answered from the model estimation was whether or not electrification had an effect on farming practices, such as irrigation and multiple cropping, not on whether or not rural electrification had a direct effect on the increase of crop yields. Thus, the dependent variables were measured in terms of (1) percent area irrigated in the village, (2) percent area double-cropped, (3) an index of agricultural innovations (such as fertilizer, green manure, hybrid use), and (4) the number of grain mills in the community.

The model estimated was;

$$Y = a + bX + cG + dZ + e$$

The vectors of independent variables X, G and Z were defined as follows:

X : village characteristics

X_1 = village population

X_2 = percent of literacy

G : electrification variables

G_1 = years since electrification

G_2 = $G_1 * G_1$

G_3 = G_1 * rainfall

Z : other infrastructure variables

Z_1 = proximity to schools (index 0-8)

Z_2 = proximity to banks (index 0-4)

Z_3 = proximity to agricultural services (index 0-8)

Z_4 = proximity to transportation (index 0-12)

Z_5 = proximity to mass media (index 0-16)

Z_6 = proximity to markets (index 0-8)

and e is a random error term and **a**, **b**, **c**, and **d** are parameter to be estimated. In order to incorporate the data gathered in 1966 and 1980, all of the variables except **G** were prepared by subtracting the data gathered in 1966 from those in 1980.

The effect of rural electrification on well irrigation and on multiple cropping was found to be significant and positive. (The authors also found that the Indian government allocates more of its funds for rural electrification to large villages and to villages near urban areas than to small, remote villages.) In general, the longer a village had electricity, the more likely it was to have higher than average increases in well irrigation or multiple cropping. This finding is relevant to water-sector planners because it suggests that one should carefully examine how long it will take after the installation of a water-supply system before the full benefits of the improvement will be obtained.

The authors found that rural electrification had a significant positive effect on both the adoption of tubewell irrigation and multiple cropping. This study is interesting in another respect. It uses aggregate data from a large number of villages. A comparable study of the effect of water-supply investments on village-level economic activities would be quite interesting, although to date such a research effort has not been undertaken.

4. Studies of the Impact of Road Construction on Regional Economic Development

There are numerous studies in the literature that attempt to estimate the effect of road construction on economic development (Jones, 1964; Carnemark, Biderman, and Bovet, 1976; Schroeder and Sisler, 1971). Most use a similar research design: an *ex ante/ex post* comparison of two areas with and without a road project. For example, Jones (1964) used a secondary data set to investigate the role of the East West highway in the economic development in Thailand. The scope of the study was not confined to the changes in traffic patterns. It also included an analysis of the economic impact of the highway on the areas that the highway passed through.

In order to analyze the impact of the improved highway, Jones selected two groups of towns. One group of towns—the treatment group—was located within a regional administrative unit that the highway passed through. The other group of towns—the control group—was selected from a region adjacent to the first one, but through which the highway did not pass. The author argued that the two regions had roughly comparable environmental conditions prior to the construction of the highway. The selection of towns in each region was not based on random sampling procedures, but on the subjective judgment of the author.

The output indicators studied did not measure economic benefits in terms of changes in individuals' welfare. Rather, Jones used secondary census data on agricultural production, forestry products production and other business activities from government publications and compared these data between the two groups of towns over a six-year period starting three years prior to the initiation of the road project and continuing until three years after the completion of the road project. Most of the production outputs were measured in terms of metric tons per year, and business activity was measured in terms of the number of small manufacturing and processing establishments in each year for selected towns. Simple regression analyses were done relating production output to time. From the comparison of the slopes of regression lines (x-axis is study years, and y-axis is the percent increase of production output), the author showed that the production levels in the treatment areas increased significantly just after the construction of the road project, while the production levels of the control group stayed at the same level or just continued increasing at their preproject rates.

One of the advantages of this research design is its simplicity and ease of implementation. Defining study units according to existing census boundaries, the author was able to gather secondary data easily. If the treatment and control group of towns had been randomly selected, and if the sample size had been larger so that the significance of differences between the two groups could have been tested statistically, then the confidence one could place in the findings would have been greatly improved.

The collection of baseline data and the widespread use of a control group strengthens the findings of the road construction project study. However, the treatment (i.e., the road project) can never be randomly assigned, and the design suffers from the possibility that the areas with and without the road projects are systematically different for reasons other than the construction of the road project, and that the changes attributed to the road project may in fact be due to these other reasons. Also, the unit of analysis is typically not a household or individual economic activity, but rather an administrative or political unit. It is not possible to understand *how* a road project influences changes in economic activity at this level of aggregation.